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Development of an Intuitive Shift-by-Wire Gear Selector

Bachelor Thesis in Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Bachelor of Science Thesis

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Pictures are created by the design team, if not specified otherwise.

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Cover
The final concept Flipswitch, explained in detail from p. 50

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ABSTRACT

In the automobile industry, a generational change is occurring for vehicles with automatic transmission. The upcoming electronic gear-shifting system, called shift-by-wire, offers among other things a smoother transaction between gears and replaces the current mechanical coupling. Shift-by-wire also gives an enlarged freedom of gear selectors' design, but users are yet finding it hard to accept non-conventional appearances. Consequently, Kongsberg Automotive suggests that one solution can be to fill the knowledge gap with an intuitive gear shifter, which is the purpose of this project.

Through researching intuition and interaction possibilities, as well as studying current legislative demands, it is found that understandability, existing knowledge, haptics and feedback are important tools of evaluating the potential of ideas and concepts produced in this project. Well recognized methods of product development are used to generate design concepts of gear shifters that correlate with the research.

The final concept connects simplicity, recognition and technology. It fulfills the purpose of this project by offering intuitive interaction through a simple shift pattern, grip friendly design and easy maneuverability. The design team believes that it will be perceived as intuitive and easy to use by a large group of various users.

Keywords:

Intuition
Intuitive interaction
HMI - Human Machine Interaction
SBW - shift-by-wire
Electronic gear-shifting system

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Lena Andersson

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1. INTRODUCTION

THIS INITIAL CHAPTER DEFINES THE BACKGROUND, SCOPE AND PHASES OF THIS PROJECT.

1.1. BACKGROUND

Kongsberg Automotive (KA) is a global actor and subcontractor in the automotive industry where one of their product areas is shift-by-wire (SBW) for passenger cars. SBW is a collective name for electronic gear transmission, which implies that the mechanical coupling between the gear shifter and the gearbox is replaced by an electronic steering. In the generational shift to an electronic gear selector possibilities will be opened for automobile manufacturers' design departments to deviate from the design of the traditional concept of gear shifters. The traditional shifter has its shape due to the leverage effect needed for a mechanical shifter, while an electronic shifter does not need the leverage effect at all.

The design possibilities of gear selectors for cars has by SBW technology been broadened, as it does not need to be attached to the traditional center console and its previous limitations. However, this new technology puts entirely new demands on the interaction with the driver as it deviates from the traditional shifting behavior in many regards. SBW has not yet reached full acceptance and understandability among the users, and KA reckons that a remedy to this is to design the interface of the gear selector more intuitive.

1.2. AIM

The aim of this project is to design the interface of an intuitive electronic gear selector for cars with automatic transmission (AT). This gear selector shall be appropriately designed for a modern driving environment, be based on current legislative demands (FMVSS 102 and FMVSS 114), and have the ability to communicate effectively with the driver both in a haptic, visual and possibly audible way. The result shall be based on the SBW-technology and does therefore not need to be limited to the design of a traditional gear shifting concept, nor to a joystick concept that has become a common solution in this transition phase towards an electronic and leverage-free gear selector.

It is important that every user, either they are practicing driving or have had a driver's license for a long time, directly understands how to use the system and thereby is able to shift gear and change the car's driving direction. Therefore, this new type of gear selector needs to have a learning curve as low as possible.

1.3. DELIMITATIONS

This project is limited to the interface design of the gear selecting system, meaning the part of the technology you as a driver use to communicate with the system. Mechanical features and computing, as well as electronics and signal processing, are overlooked. Safety aspects regarding the design in the occurrence of a collision will be left out. Furthermore, cost estimations will not be considered in the frames of this project.

1.4. RESEARCH QUESTIONS

- How can a shift-by-wire gear selector interface be designed to be perceived as highly intuitive?
- How does interaction with the driver take place to change gear and driving direction as effective and intuitive as possible?
- How is the design possibilities directed of current legislative demands?

1.5. PROJECT OUTLINE

The project and report follows a traditional development pattern where iteration occurs, shown in figure 1.1 below. The report has four main parts; introduction and theory, development process, final concept and ending chapters.

Introduction and theory is covered in chapter 1-4. Chapter 1, *Introduction,* contains a traditional presentation of the project's scope, followed by chapter 2, *Methods*, where all methods used throughout the project are displayed in the order they are used. Chapter 3, *Theory and Market Research*, shows research and results of subjects relevant to the scope of the project and chapter 4, *Sustainability Analysis*, presents the environmental frames of reference used by KA and thereby this project.

Chapter 5-7 contains the development process, where chapter 5, *Idea and Concept Development Process*, describes the initial ideation up to presenting nine idea concepts. Chapter 6, *First Concept Elimination*, and chapter 7, *Second Concept Development and Elimination*, takes the reader through the two stages of elimination and a small section of development in between.

The final concept is described in detail in chapter 8, *Chosen Concept*, where design, materials and HMI are presented. The ending chapters of 9, *Discussion*, and 10, *Conclusion*, summarizes the report and project in standardized measures.

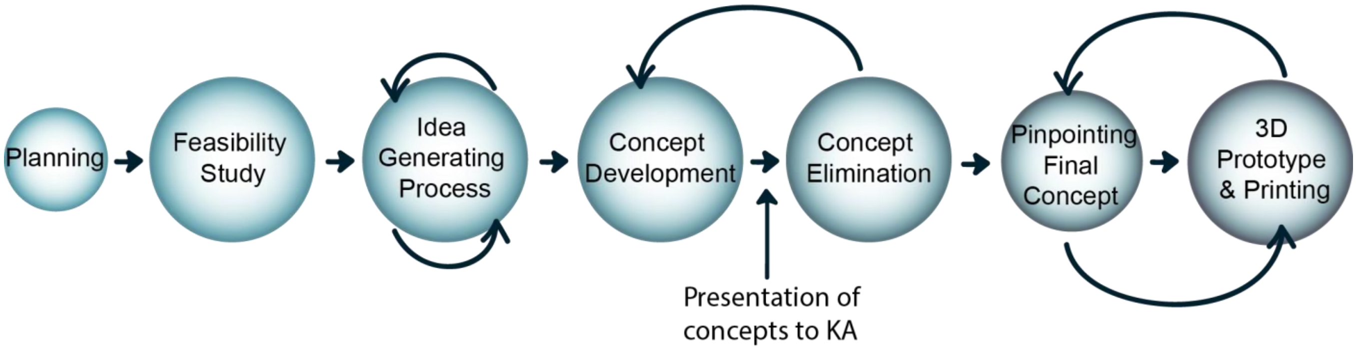


Figure 1.1: The product development process, accustomed to this project [1]

2. METHODS

THIS CHAPTER CONTEMPLATES ALL METHODS USED FOR DEVELOPMENT, ANALYSIS AND ELIMINATION OF CONCEPTS, AS WELL AS THEIR APPLICATION ON THE PROJECT.

2.1. METHODS FOR RESEACH

When a technical project has been identified and specified, research is conducted in order to gather the information needed to proceed with finding a solution. The data collection shall be conducted objectively and rationally, where information about prerequisites, technology and previous research is identified and gathered.

2.1.1. Time Management - GANTT

As for any project, it is important to distribute the given time as efficiently as possible. A GANTT-chart is a perspicuous way to show how much time is estimated for each step of the design process [1]. In an activity-time diagram, each step is given its own line and the estimated start and finish date is visualized with a horizontal bar. The GANTT-chart can be updated throughout the project.

The GANTT-chart provided an easy overlook of this project and ver. 2.1 is found in appendix 1. In addition to the chart, a weekly calendar has been used to fill in day to day activities.

2.1.2. Literature Studies

A literature study is carried out in order to create insight of the subject and collect relevant information [1]. The source can for example be regulations, reliable research articles, published works and books. The information is used as the foundation for an upcoming requirement specification and further work in the project.

In this project, information about relevant laws, SBW, intuition interaction and anthropometry is mostly gathered through online library search motors. However, since the connection between SBW and intuition has to the design team's knowledge not yet been explored, the two subjects are researched separately. The literature study is done in the early stages, to provide the team with substantial knowledge for the later stages.

2.1.3. Market Research

A market research can be conducted in many ways, depending on what information is relevant for the project and which results are desired. Commonly, surveys, interviews and focus groups are used for seeing the needs and wishes of stakeholders, as well as potential customers and users [1]. If there is an existing market where the projected end product fits, it can be examined.

The needs and wishes of this project correlate with the aim given by KA. Because of this, no formal interviews or surveys are carried out. Instead, a more relevant and factual approach is chosen for exploring the current market in two steps. First by doing a field study where seven cars with SBW gear selectors are to be tested, thereafter with a benchmarking analysis.

Field Study

To make the field study similar to a renting car situation, introductions from salespersons are refrained and the only knowledge available is the project group's own. Before starting the car, the initial impressions of the car and gear selector are noted. Each test takes about 30 minutes, where both members of the team tests accessing and using the gear selector's gear options and shift pattern. Haptics, comprehensiveness and usability are evaluated, as well as the manual gear selecting system (if available). While parking, the ease of switching gear quickly is analyzed. Finally, failure in reaching the desired gear and accessing the wrong gear by accident is tested.

Benchmarking Analysis

A benchmarking can be done in different ways, but is essentially a market research [2]. In this project, the benchmarking means researching and analyzing the interfaces of SBW gear selectors found in existing and concept cars, and is conducted early on in the idea generation. About 260 pictures of different gear selectors are acquired from the A2Mac1 Automotive Benchmarking database. The ones that the design team finds interesting in one way or another are chosen and set into a collage for the writers to have as a reference during the ideation process.

2.2. METHODS FOR IDEA GENERATION

The idea generation phase is where ideas for solutions are created and concepts begin to take shape. Various acknowledged ideation methods can be used, but it usually starts with a requirement specification, where the deliverables and aims of the project is listed [1]. The purpose of the idea generation process is to deliver concepts for evaluation and further development or elimination.

The process of this entire project is iterative, which is extra distinct within the idea generation process. The process is shaped around idea generating methods, but during the process the writers goes back and forth among these. Associations and ideas are created and built on each other. The research creates the structure for a requirement specification, and together they set the guidelines for the idea generating process, producing a variety of starting concepts to develop further.

2.2.1. Requirement Specification

The requirement specification is a document listing criteria which the final solution shall fulfill [1]. The criterion can either be required or desired and shall be as clearly defined as possible, so they can later be validated. A required criterion must be met under any circumstances, otherwise the solution will not be approved. A desired criterion shall be met if possible. The requirement specification may be updated continuously throughout the project and thus become more specific. It serves as a bridge between the research compilation and ideation. It is a very important step in product development, since it sets the rules for the idea generation and following concept management.

2.2.2. Random Words

Random words is a method where you force yourself to come up with ideas by using randomly selected words from a dictionary, newspaper, word generator or something else that can provide you with words [2]. The point is to make associations based on these words, which perhaps have nothing to do with the actual problem, and to go outside the path set by the problem. It is often the spontaneous associations that in the end provide good ideas.

In this project an online word generator [3] is used, and there is a time limit set to 40 seconds for each word, to prevent getting stuck on one word for too long. The associations may then be valuable combined with other methods.

2.2.3. Placement Evaluation

The placement evaluation is inspired from a method called Focus Areas, which aims to stop the ongoing process and look at specific focus areas instead of generating general ideas [4]. It is used to prevent uniformity early in a process and encourage the team to seek new ideas rather than build upon one idea.

The placement evaluation is conducted as a part of the idea generation to define, but not limit, where in the car interior the gear selector can be placed. This step is supposed to guide the design team during the ideation process, and let them focus on one placement at a time and thus not get overwhelmed by all possibilities, or fixed at only one placement.

2.2.4. Idea Playing Cards

The idea playing cards is a method of idea generation that aims to increase the individual creativity and amount of ideas [4]. These playing cards consist of 48 different questions or statements that all aims to trig new thoughts and ideas. It is supposed to fit all kinds of problems and challenges, and different idea generating methods can be found within it. For example, the Question Method with questions such as "how common is the problem," SCAMPER that works on fragments of ideas, thinking "can it be modified somehow", and Biomimicry that asks "how would nature solve the problem".

In this process, the idea playing cards are used as a complement to the other idea generating methods, especially during the free sketching, where a random card can be taken when more input is needed.

2.2.5. Free Sketching

Free sketching, or thinking in pictures, concerns simple idea sketches integrated in the idea generating process [1]. In an early phase it can be seen as a support for scribbling down ideas and concretizing personal thoughts. In a later phase it can be seen as a conveying tool to express the idea to an external observer. A sketch can in the later phase be more detailed, and for instance be put in an environment to explain the size of the product.

Since the aim of this project is to design a product, free sketching was used the most during the idea generation, with the previously mentioned ideation methods as help and guidance. Pictures and explaining text are all combined on a large amount of papers. The method is also used in order to present the ideas for KA.

2.2.6. Brainstorming Session

In a brainstorming session, the goal is to produce a large quantity of ideas that can be further developed [2]. The ideas are to be left uncriticized during the session and do not have to have a high quality. It is commonly conducted in a group with discussion. The ideas can be written down and/or visualized on a large mind map or individual post-its. Food and beverages are a positive element sometimes used to raise the blood sugar level and thereby extract even more ideas.

For this project, the attendees discussed and drew their ideas on a combined large paper, with the incentive of later being served tacos and cake. The brainstorming session was carried out after the design team's own idea generation, to see if even more ideas could be found.

2.3. METHODS FOR CONCEPT ELIMINATION

In a product development project, an elimination process usually follows creation. The concepts are objectively evaluated through different means and criteria. This builds a good understanding for how well the ideas meet the requirements, reduces the number of concepts, and highlights the ones with highest potential.

About ten idea concepts will be created in the concept developing phase, with describing text and pictures. This projects elimination will be done in two intervals, using several different methods with the aim to see each concept from every angle. After the first elimination, three concepts will remain and be created in physical models, revised once more and put up for a final elimination.

2.3.1. Presentation of Concepts for KA

When a project is assigned from a company, a valuable step in the elimination can be to listen to its employees expert opinions. Through that contact, the project group can apprehend what the company thinks about the progress and which concepts they see as feasible solutions.

The prepared idea concepts will be brought to KA, to present and discuss them with a group of employees experienced with gear selectors. The ideas will be visually presented with complementary text. The aim of the presentation will be to hear which concepts KA believes have the highest potential.

2.3.2. Pugh´s Weighted Decision Matrix

As a tool for organized evaluation and elimination, Pugh's decision matrix can be used [1]. Different criteria are made based on the research and requirement specification, and put on one axis. Each criterion is weighted to match their importance to the final result. A market standard object and the group's concepts are put on the other axis. The concepts are compared and graded with -, 0 or + on the different criterion to decide if the new solution is worse, same or better than the standard object. After summing up the results, the concepts with lowest points may be eliminated.

In this project, Pugh's matrix will be the first elimination matrix used. It is decided to be weighted because some criteria are deemed more important than others for the acceptance of the end result.

2.3.3. Criteria Scoring

Criteria scoring, sometimes known as Kesselring matrix, is a decision matrix used to grade or rank the concepts. The same criteria can be used as in Pugh's matrix, as long as they have an influence on the end product's acceptance [1]. A more important criterion can be weighted with a higher point. The concepts get points for how well they meet each criterion; zero points if the criterion is not met and up to three points if the concept is fulfilling the criterion very well.

As the second elimination method for this project, the criteria scoring matrix has some changed criteria compared to Pugh's matrix. Even though the results might be similar to Pugh, the criteria scoring is valuable because it is here used stricter and does not use a market standard object, but evaluates the concepts in comparison to one another.

2.3.4. Mockups / Clay Models

Mock-up is a technique used for creating a quick physical model of the concept, using for example a modeling clay or foam material, preferably without a fiber structure [1]. The model does not have to endure function testing, since the purpose is to evaluate shape and possibly surface and color. Common things to consider through the mock-up are also size, roundness in edges and ergonomic properties. Since it is a relatively quick process, compared to making the finished product, the mock-up saves time and allows adjustments before the final product is created in a more durable material and in more detail.

In this project, mock-ups will be made for the three concepts remaining after the first elimination process. Modeling clay and modeling utensils is to be used and when finished, the models will be hardened in an oven.

2.3.5. PMI Analysis

The PMI (plus, minus and interesting features) is a version of the Six Thinking Hats where pro's and con's of each concept is individually discussed [4]. It is important to keep both the concepts and the positive and negative critique separated from one another, to avoid conflicts and contradictions. The interesting features are then highlighted. This analysis is helpful to organize opinions of each concept.

When utilizing the PMI tool, the interesting aspects will be organized in three ways. First by importance, taking into account both positive and negative opinions. Second by changeability, if a negative aspect could be changed to make it positive, and finally if it is redundant for this project. With aid from the PMI analysis, adjustments might be made to the three concepts before making the final elimination.

2.3.6. Comparison Matrix

A good way to evaluate concepts in relation to each other is to compare them. Through the comparison matrix, the concepts are put against each other, one criterion at the time [2]. This can be used either in an early stage, where several concepts are compared and then refined or eliminated, or in a later stage with only a few remaining concepts, to make the optimal final decision.

Here, the comparison matrix will be used as the last evaluation and elimination tool. Inspired of the PMI analysis, criteria from Pugh's matrix and the criteria evaluation matrix are reconsidered and tweaked into adaption of the evolved state of the concepts. As a result of the conducted comparison matrix, only one concept will remain.

2.4. METHODS FOR CREATING THE FINAL CONCEPT

The final concept will be produced as a 3D-printed CAD prototype. When creating this prototype, focus will be put towards showing its intended design attributes. The mechanical and electrical features are not within this project's scope and will therefore remain to be developed later on. Consequently, this prototype will not be a product ready for production.

A final prototype will be printed with KA's SLS 3D-printer with very high resolution. This prototype will then be sent to professional varnishing. The goal with the finished prototype is to demonstrate the aesthetic attributes, colors, text, and at least one position of the shift pattern. It will in this stage not offer the feedback attributes nor right material.

2.4.1. Rapid Prototyping

Rapid prototyping can be used similar to mock-ups, as a quick and easy way to validate a physical model through shape and size. Rapid prototyping is however made with Computer Aided Design (CAD) [1], where the prototype then can be either 3D-printed in plastic, or produced in a CNC machine, often using simple material as foam.

When the final concept is chosen for this project, it will be made as a 3D model using Alias Automotive and Catia V5. Since the aim is to deliver a relevant gear selector prototype to KA, the concept will be printed in 3D more than once, where the first print is the rapid prototype. The prototype will verify that size, shape, angles and rounded edges all correlate. Potential attachment components will also be printed. If some changes are needed, they will be made before making another, more detailed physical model.

3. THEORY AND MARKET RESEARCH

THIS CHAPTER PRESENTS THEORY OF RELEVANT SUBJECTS LEARNED THROUGH RESEARCH, AS WELL AS INTERACTION WITH EXISTING SBW GEAR SHIFTERS LEARNED BY TEST DRIVING.

To understand the shift-by-wire technology and the possibilities of using its gear selector interface intuitively, both areas are researched and presented. First, regarded laws are presented, followed by the evolution, function and advantages of SBW, and a test-driving field study where seven different SBW solutions are explored. This subchapter, *3.3 Some Existing SBW systems*, is written in first person, since the authors' own opinions are presented. Since the connection between SBW and intuition has been scarcely explored before, a thorough intuition study is being presented in *3.4. Intuition Research.*

In order to be prepared for the design process, research about interaction input and output possibilities for interaction with interfaces are made in 3.5. Because of the group's strive of thinking outside the box, the market research of interaction possibilities is kept brief. Anthropometric data on hands is used together with the research for creating understandability for in-vehicle human-machine interaction (HMI). The results regarding SBW, intuition, interaction and anthropometry made in the theory and market research will be taken into account in the design process presented in chapter *5. Idea and Concept Development Process*.

3.1. LAWS

Kongsberg Automotive directed the design team to take law FMVSS ch. 102 and 114 into account when test driving cars and designing the gear selector. The laws concern the transmission shift position, transmission braking effect and rollaway protection and applies to cars with automatic transmission (AT). The design possibilities for the intended gear selector are directed on the shift pattern's interface, stating for example where in the sequence P is allowed and that the shift pattern should always be visible to the driver. The paragraphs relevant for this project are interpreted and found in the requirement specification in chapter 5.1. The extracted paragraphs can also be found in full length in appendix 2.

The laws are at times far-fetched, and hard to interpret and apply to a SBW gear selector. According to KA employees working with SBW, the flaw is due to that the laws are written for a mechanical AT and probably need revision to be better adaptable for SBW.

3.2. SHIFT-BY-WIRE

A traditional AT system contains of a gearbox by the engine, a gear lever in the center console with which you choose propulsion direction, and a connecting cable between them, working as a mechanical lever [5]. With AT, the engine changes gear when the car is in the appropriate speed and the driver only needs to decide whether the car should drive forwards (D), backwards (R) or be in neutral mode (N). A park mode (P) is usually provided, which prevents the car from moving.

SBW is an electronic gear selector, developed to fit the traditional AT and its subcategories continuously various transmission (CVT), dual clutch transmission (DCT) and automatic manual transmission (AMT). With this technology, the cable is eliminated and instead electro-mechatronic signals connect the gearbox with the gear selector [6]. When the driver selects propulsion direction, the signal is wirelessly transmitted to a gearbox receiver. When changing gear with mechanical transmission, the lever stays in the selected gear. With SBW, the gear selector is often monostable; meaning that after the user changes gear, it returns to its original position (usually) in the middle of the console.

In many existing cars with SBW, an AMT is used. It is "an intermediate technological solution between the manual transmission used in Europe and Latin America and the automated transmission popular in North America, Australia and parts of Asia" [7]. With this transmission, the driver can either go forward in D or A, where the gearbox selects the gear, or in S (sport), B (engine-brake) or M (manual), depending on brand of car. In the M-mode, the driver manually selects the gear by, depending on the vehicle, either pressing up- and downshift paddles or buttons on each side of the steering wheel, or by moving the gear selector to the side and then forwards or backwards for lower or higher gear. The AMT system was integrated in passenger vehicles after several years of use in sports cars, where it was used due to faster and smoother gear changes [7]. Compared to a traditional manual transmission, no clutch is needed. AMT also allows a stronger feeling of being in control than the AT and allows a higher degree of engine break, which is also the main purpose of the B-mode. This might come in handy when driving downhill when the normal drive of the D-mode might encourage you to hit the brake lightly, causing unnecessary wear on the brake. S can sometimes be found in the shift pattern, which delays the shifting to maximize the acceleration.

There are several other advantages of SBW compared to a mechanical gear changing system. For developers, the freedom of design is enlarged, both for the placement and interface of the gear selector [8]. Now, the gear selector can be mounted not only on the conventional place on the center console, but anywhere in the car interior [9]. Today's existing designs vary from a "joystick" similar to a traditional lever, to buttons, rotary controllers etc. Furthermore, the electronic gear selector is lighter than the cable, which helps reduce fuel consumption, and this system is also less sensitive for temperature changes. For users, some of the advantages lies in improved smoothness of gear changing, automatic parking possibilities and reduced road noise, since the hole into the engine space for the cable is no longer needed [9].

Issues with SBW lies mostly in expectations. If a user expects the gear selector to look and operate as a conventional automatic lever, they might get confused if the design is severely different, by the monostability or when the applied force needed is much smaller than anticipated [8]. This causes for haptic dissonance and could lead to a repelling attitude. How viable the gear selector is depends on how intuitive it is; how easily it is understood and how quickly the user learns to operate it without looking at it.

BMW introduced the first SBW system for passenger vehicles in the 2001 7-series [10]. Going for a big change, the lever was mounted on the right side of the steering wheel. Unfortunately, both the instrument cluster and lever was perceived as too complex [8]. A few incidents in North America where the car moved in the opposite direction than the driver intended, or the driver was not able to access Park mode, gave SBW a rocky start [11]. Since then, better and more trustworthy solutions have been developed and now many of the big car producers have presented SBW solutions for some of their series. Usually, the first series to receive a new and exciting feature is the expensive and sporty ones, but now SBW can also be found in lower price class series.

3.3. SOME EXISTING SHIFT-BY-WIRE SYSTEMS

When researching the possibilities with SBW and the differences from the traditional automatic gear selecting system, the authors headed out to car retails to test drive seven different cars with different existing SBW solutions to get a hands-on experience. The cars tested are the 2014 models of Nissan Leaf, Toyota Prius, BMW 520, BMW i3, Mercedes-Benz B180, Land Rover Discovery, and Abarth 500. The general gear selecting designs provided by these cars are the traditional joystick, a puck, buttons or a steering wheel mounted lever.

3.3.1. Nissan Leaf

As the first car to test drive, Nissan Leaf delivered an exciting perspective on how different SBW can be from a traditional gear selecting system. This fully electric car's gear selecting solution is mounted on the center console and has a knob-like appearance made in silver colored plastic with a front-facing bright blue plastic surface, see figure 3.1a on the next page. The shift pattern is displayed without backlight and below the knob, so your arm might cover it from view while changing gear. Luckily, the chosen gear is also well displayed on the instrument cluster. The knob feels a bit small and is surrounded by an unreasonably big silver circle. However, the knob design still maintains the traditional feeling of a lever design. We perceived the material, size and interface as interesting and cool, but plastic and slightly uncomfortable.

When changing gear, the knob is first moved to the left, and then front for accessing R, back for D or held in left position for N. If pressing back one more time while in D, B will be accessed, which is a driving mode with engine brake. There is a button on the knob for accessing P. Both of us felt puzzled by moving the knob forward in order to reverse the vehicle and would have felt more comfortable having it the other way around. The knob's movement pattern is suggested by the softly triangular design framing the knob, but we felt it was contradicting the shift pattern, since the design does not allow us to go straight from start position to R or D, without passing through N. Initially, it was hard for us to access N, since we did not understand that the knob needed to be held in left position. We were also not sure what B meant, until the sales clerk enlightened us after our test drive. Furthermore, there is no audible feedback for selected gear, the car had a nice steering wheel with heating and was very smooth to drive.

3.3.2. Toyota Prius

The Toyota Prius gear selector is a joystick of about half the size and height of a traditional gear lever, positioned on the center console just below the ventilation control, see figure 3.1b. The center console itself is rather high and allows armrest. The joystick is surrounded by a broad silver circle, has a plastic silver base and a tilted transparent blue top, where the shift pattern is displayed. The shift pattern is further presented by a h-shaped movement pattern at the base of the joystick. The whole shift pattern is also visible in the instrument cluster, with the selected gear highlighted. Park position is selected through a P-button placed in front of the gear selector. Even if the joystick is small and thereby felt a bit uncomfortable, the quality and interface was very appealing and the full experience was pleasant.

To change gear, the joystick is first moved to the left, and then up for R, down for D and held to the left for N. Once D is selected, we can choose to go down once to access B, similar to the knob in Nissan Leaf. Another similarity to the Leaf system is that both of us felt it would have been logic to push the joystick forwards to access D, leading to both of us selecting the wrong gear at least once. When reversing, there is a continuous beeping noise so loud we wished to be done with reversing as quickly as possible, which was very stressful.

3.3.3. BMW 520

The gear selector found in BMW 520 has more traditional characteristics compared to some of the other tested SBW systems, see figure 3.1c. It is designed as a joystick with similarities to traditional shift levers, and is therefore easy to use based on past experiences from a mechanical AT. The size and shape of this joystick makes it comfortable to hold and use for both of us, and we assume it is ergonomic for people with both smaller and bigger hands. Its design was perceived as nice, fairly classic, but also technical with a qualitative and clean interface. It has a display facing the driver with the shift pattern and light indicators showing which gear is selected. The pattern is R-N-D, meaning R is selected when the joystick is moved forward. Manual gear shifting is made possible by pushing the joystick to the left in drive mode. The hand might hide the shift pattern while using the joystick, but the selected gear is also shown on the instrument cluster. On the top of the joystick there is a P-button, and at the left side another button with the text "unlock", which is not fully visible and it is at first unclear what its function is.

Figure 3.1: Gear selectors of a) Nissan Leaf, b) Toyota Prius and c) BMW 520 in models of 2014

The overall impression of this gear selector is good, but there are three things we would like to comment upon. The biggest complaint is the unlock-button which, as mentioned, is not clear how to use. At first we thought it needs to be pressed during every gear change, maybe due to its convenient location for the thumb. After a while we realized it is a safety-button that prevents us from accidentally access R or get out of P. While using it as we first thought, we accidentally got into R position in a higher speed than appropriate, which makes us argue that this safety-button does not provide the security it was meant to.

The second complaint is about the manual shifting, accessed from D by pushing the joystick to the left. When shifting manually, the joystick is pushed forward to gear down (-), and backwards to gear up (+). We would have felt more comfortable having it the other way around, in the same manner as with R and D in this system, as well as in Nissan's and Toyota's gear shifting systems. During manual gear shifting the chosen gear is shown at the instrument cluster. A great range of gears is available, such as S2 where S stands for sport, which contributes to confusion. The third notable thing is that the instrument cluster gives a lot of information when the system is not correctly used. For example, if you do not press the brake and the unlock-button while moving out of P, a message tells you to do so. We argue that the less information needed, the better, so if the system was designed more intuitively, the information messages would not have been necessary.

3.3.4. BMW i3

BMW i3 is a small fully electric car with a great "city car"-feeling. Its gear selector is a console placed behind the steering wheel on the right hand side, above the windscreen wiper lever, see figure 3.2a on the next page. The design is relatively big and ergonomically fitted to the hand, which makes it easy to understand and use even though it does not look like a traditional gear lever. By turning the console's moving part forward with your hand, D is selected, which both of us perceived as logical. By turning it towards you (the driver), N is selected in the first step and R in the second step. P is accessed by pressing a button on top of the device. The shift pattern is shown on a display with light indication on the fixed part of the console, located on the left side of the moving part, so it does not get covered by the hand. The engine start and stop button is placed at the far left side on the console, allowing you to find the gear selector while looking for this function. This small car has an unusually high amount of engine brake, which may be a great feature in city traffic.

The impression we got from this gear selector is that it certainly is a great match for this car. The entire interior, and especially the instrument panel is a little offbeat which makes this unconventional gear selector a perfect fit. A big disadvantage that quickly emerged was that the steering wheel spokes hid the console in some positions, and therefore also the start/stop button. However, a great advantage is that the console encourages you to hold both hands on the steering wheel, since it is easy to reach from that position. It does therefore not encourage you to hold your right hand on the actual device as a center console-mounted gear lever or joystick may do.

Another advantage, due to the location of the gear selector and the lack of a traditional center console, is that a lot of space is added to the user's advantage. This makes it possible to easily move between the driver's seat and the passenger seat. The necessity of this can be argued for, but perhaps if being parked closely to an object. However, we can point out that this interior design would not have been possible without SBW, since the cable would have been there.

3.3.5. Mercedes-Benz B180

The Mercedes-Benz B180 has, just like the BMW i3, a gear selector located behind the steering wheel, on the right side where the windshield wiper lever is normally found in many cars, see figure 3.2b below. The shape is even very similar to a windshield wiper lever, but slightly shorter. The gear selector has a backlit display showing an understandable shift pattern, but without indication of which gear is selected. The selected gear is instead shown in the instrument cluster, where you also can see the interactive shift pattern, telling you how to move the lever to choose the intended gear. That is an almost necessary feature for first-time users, since the gear selector and its shift pattern is easily hidden behind the steering wheel spokes. When shifting from N to D, the lever is pushed downwards, and the opposite direction to access R. P is accessed through pushing a button at the tip of the lever. Since these movements were not obvious to us, we found the interactive shift pattern very helpful.

The windshield wiper lever is located on the left hand side of the steering wheel in all of Mercedes-Benz's models. This was confusing for us, especially since the test drive was conducted on a rainy day. We had to pay attention to both a new gear selector, and another location of the windshield wiper lever. Both of us automatically tried to reach the gear selector to start the windshield wiper. The gear option N was once accidentally chosen while driving forward due to this automatic habit connected to muscle memory. The reason why it did not happen more times is because of the earlier mentioned length difference. Similarly, the turning signal was once chosen instead of the windshield wiper. The right hand was also out of habit willing to move towards the center console while searching for the gear selector.

The overall experience from this test drive was significantly different from what we got from BMW i3, that has the gear selector placed at a similar location but with a different shape and in a different interior environment. The Mercedes-Benz salesperson commented the placement of this SBW solution as "back to the old school."

Figure 3.2: Gear selectors of a) BMW i3 and b)Mercedes-Benz B180 in models of 2014

3.3.6. Land Rover Discovery

The Land Rover is very big compared to the other cars we tested. Even though it has a lot of buttons and features, the dashboard has a clean look and the gear selecting system fits well into it. When taking a first look into the car, we were not quite sure how to use the gear selector, since it looked like a flat black circle with a silver edge on the center console, and nothing like a traditional gear shifter. We could tell it was the selector by the shift pattern, which is displayed on a P-R-N-D-S row above the circle, see figure 3.3a below. However, once the car is started the circle is elevated into a puck and it is clear to us that we need to turn it in order to change gear. The puck has a smooth top surface and striated side, so we get a decent grip. The selected gear is shown both in the instrument cluster and as illuminated red letter on the shift pattern. The S-mode is reached by pressing and turning the puck while in D. It is according to the sales clerk designed to be more explosive and allows the driver to change gear with paddles behind the steering wheel.

We found this gear selecting system clean and easily maneuvered, but perhaps a bit plastic in regards to the high quality of the car. The right arm can be rested on an armrest, but if there is a cup or bottle in the cup holder, positioned between the armrest and gear selector, it would interfere. We also think it would be suitable to have a prevention from reaching R once driving faster than 7 km/h, since we were able to access R when driving 30 km/h. The car then slowly halted and once driving sufficiently slowly, started to reverse with a jolt. Furthermore, since it is a huge car, it was hard to park as it lacked visual or auditory aids to let us know how close we were to surrounding objects.

3.3.7. Abarth 500

After testing and seeing different SBW systems, we were excited to try the Abarth 500's push button system. The first impression is good - the buttons are clearly visible, the design is understandable and we believe a person with no previous knowledge of such system may understand how it works, see figure 3.3b. The four buttons are put a little to the right in a big circle on the center console, in a triangular pattern. The A/M button to the left lets you choose between automatic and manual gear

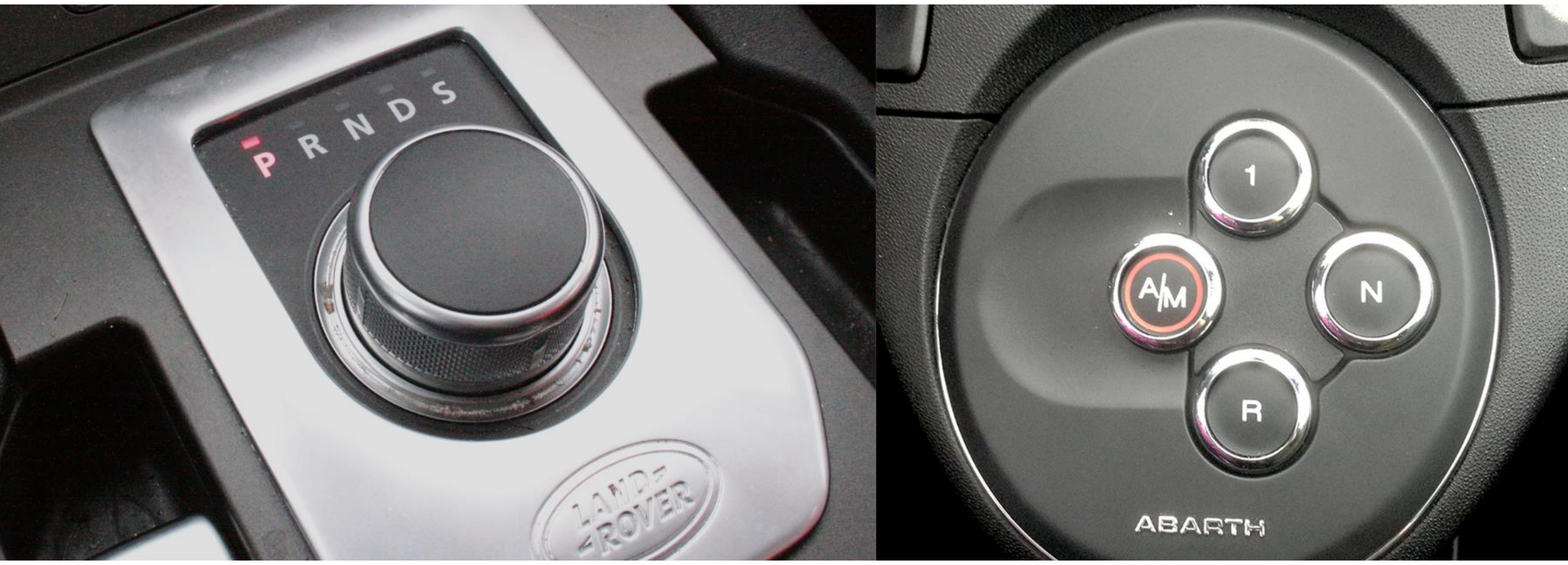


Figure 3.3: Gear selectors of a) Land Rover Discovery and b) Abarth 500 in models of 2014

selection, R is found at the bottom and N to the right. Furthermore, there is no P button, but a confusing "1-button" that we realized is the option for forward propulsion. In M-mode, we can select gear by pushing + and - paddles behind the steering wheel, and in A-mode the car decides the gear itself. Whether we are in auto or manual mode is displayed on the instrument cluster, as well as the current gear. Pushing the 1-button indicates that we choose gear 1, but this button is in our opinion not ideal. Instead, the 1-button could have been a D-button to signal drive in order to be consistent with other gear selecting systems.

Since Abarth 500's compactness is engaged within the instrument cluster, ventilation control and seating, we expected the gear selecting's panel to be compact as well. Instead, the buttons with its surrounding circle take so much space that it feels like it is actually uses leg space. Unfortunately, this test-driving experience was not satisfying. Partly because it felt like we needed to force the car into propulsion, which might have been a feature to their AMT system, but mostly because there was a transmission failure, preventing us from reaching a higher gear level than 3. The push button system was not perceived as exciting as expected.

3.3.8. Comments on the Test-Drivings

While test-driving the vehicles, some common notations were made regarding SBW and its differences and similarities with a mechanical automated gear selector. One general difference from the traditional AT is that the system is usually monostable, meaning it goes back to its original position after changing gear, instead of staying in the chosen gear's position. However, security features associated with gear selection are preserved, both with and without law enforcements. For example, it is still necessary to press the brake pedal when leaving P or shifting to R and the R-N-D shift pattern is preserved, as restricted by laws in FMVSS 102 [12].

Confusion about which direction to move the gear selector in to access a certain gear was in our case shared between four of the seven cars, where we felt that the R-N-D pattern ought to be in the opposite direction. The reason for the persistent shift pattern was explained to us by our Kongsberg Automotive advisor Jimmy Östman, and comes from the technical design of the first AT system, built with a cable in the 1930s [13]. Back then, the constructors decided that the logical thing would be for the gearbox shift operator to move backwards to access reverse and forward for drive. But since the cable is connected to a lever, which in extension is the visible part of the gearshift in the driver's cabin, the top of the lever needs to be moved forward to access R. At some point, another constructor changed this, so when the gearshift was moved backwards, the car drove backwards. Unfortunately, this confused some drivers and caused accidents, resulting in returning to the first solution. However, since SBW expands the design possibilities for a gear selector, it might be considered okay for an unconventional gear selector to have an untraditional shift pattern.

Thoughts regarding the placement of the gear selector was also noted, but the design team figured that the location is secondary in regards of usability. Of course, it might be more comfortable if the system is within reach without having to lean forward, but the importance for correct operation lies in whether the gear selector is always visible and understandable.

3.4. INTUITION RESEARCH

Intuition is a keyword given this project from Kongsberg Automotive, and is thus an essential part of the entire project. The user is supposed to perceive the final design as an intuitive interface. Therefore, this subchapter is included to define what intuition is, but also to describe how a human-machine interface (HMI) can be perceived as intuitive, and to discuss what aspects are important for the design process. The research is conducted generally, without specific focus on gear shifters, due to absence of such facts. In the end, it is important to have these aspects of intuition clearly stated, for the design team to have a solid base to stand on in the development phase.

3.4.1. Intuition

One of the first to examine the meaning of intuition was the author K.W. Wild in 1938. She looked into poetic and philosophical sources, and stated an early definition of intuition:

> *An intuition is an immediate awareness by a subject of some particular entity, without such aid from the senses or from reason as would account for that awareness* [14].

Wild's definition argues that for an item's ability to offer intuitive interaction, the user shall immediately understand how it works without knowing how to use it. Even though this definition is from as early as 1938 it is still commonly used, even though it does not differ significantly from the meaning of cognition in general. This definition can be seen as the backbone of intuition in regards of designing an intuitive HMI. In this project, it is more accurate to research intuitive use and interaction rather than merely intuition.

3.4.2. Intuitive Use and Intuitive Interaction

Intuition has too many times been implemented in the process of designing intuitive products without first defining what intuition really is [15]. The work has rather been based upon the public perception of intuition. Luckily, in recent years there has been more research regarding intuitive interaction with technical products, opening up for designers to base the work upon the results. The definitions of intuitive use made by different researchers mostly correlates with each other, and many definitions contain keywords such as knowledge, previous experience, and non-consciously. This is one of the definitions, mentioning both intuitive use and intuitive interaction:

> *Intuitive use of products involves utilising knowledge gained through other experience(s). Therefore, products that people use intuitively are those with features they have encountered before. Intuitive interaction is fast and generally non-conscious, so people may be unable to explain how they made decisions during intuitive interaction* [16].

Based on this definition there are some main indicators of an intuitive interaction. The part with gained knowledge can be linked to expectations. People would be able to use their intuition if they can expect a certain function out of a feature. Intuition is generally fast and so is intuitive interaction. Spending time on exploring features before using the correct one is not considered intuitive; the right feature should rather be used within a period of five seconds. There is also a relation between intuition and performing a task confidently. Being able to use a feature intuitively is often linked with confidence in a decision or about correctness. There is a difference between just trying a function and using a product that you actually understand how to interact with. This is not the same as processing inputs consciously and it is more likely that the interaction is intuitive if the processing requires less reasoning, which implies a non-conscious action.

When talking about an intuitive interface, it is important to point out that no product itself can be intuitive [17]. Intuition is a cognitive behavior, which makes people the ones who intuit with products. The question is not whether an item is intuitive or not, it is rather whether the item has a possibility to offer an intuitive interaction with the user or not. The design has to seem intuitive in the regard of how users understand it in the first place.

3.4.3. Knowledge Based on Previous Experience

The connection between intuition and knowledge based on previous experience seems after some research [15, 18, 19, 20] to be the most important part of a feature's ability to offer an intuitive interaction with the user. Apparently that has not always been generally recognized [15]. Intuition has been seen as something instinctive or innate and is in some extent still incorrectly linked to these words. There is no sixth sense, nor a supernatural inspiration, connected to the power of intuition [19]. Even though intuition happens non-consciously, it does not happen without reason. It is based on some kind of previous experienced knowledge and does not have to be directly attached to, say a specific interface.

A person's existing knowledge is in the intuitive process integrated with what is perceived by the senses, and new associations produce insights or judgments regarding the relevant interface [20]. An instinctive reaction could trig the process, but a fully intuitive interaction does not happen only by instinct. Neither are you born with an intuitive capacity even though intuition varies in different phases of life. A baby's intuition is primarily based on instinctively reaction on stimuli, and as it develops towards an adult with more experiences, its intuition will include more responses that are learned. Intuition and age has a connection also later on in the life phases. Younger adults complete intuitive operations much faster than adults in the age of about 40 to 60 [18].

Another intuition researcher, Jared Spool, has approached the question about what makes a design or interface seem intuitive by looking at the item's knowledge space [17]. He discusses this question with help of a knowledge bar, as seen in figure 3.4, where he puts users knowing nothing about the interface at the far left side, and users knowing everything at the far right side. In between, there are two interesting points. The first is a point of current knowledge, representing the user's amount of knowledge when first interacting with an interface. This point differ from one user to another, depending

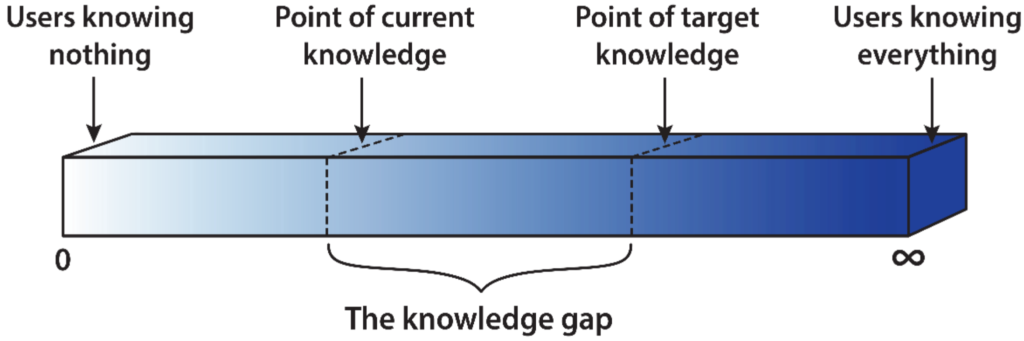


Figure 3.4: Spool's knowledge bar [17].

on their previous experienced knowledge. The second is a point of target knowledge, representing the amount of knowledge required by the user to understand and successfully interact with the interface. This point is specific for every product, but can be set to a different level by design choices. What is interesting in the regards of a design's intuitive appearance is the distance between the both points, called the knowledge gap. Intuitive interaction happens when there is no gap between current knowledge point and target knowledge point.

3.4.4. Different Types of Knowledge

There are some different types, or levels, of knowledge interesting in regards of intuition. Even though it is stated that intuition is not an innate talent, there is an innate knowledge seen as the lowest level of knowledge and a contributor to intuitive interaction [16]. This type of knowledge is what instinctive behavior and reflexes are based on, and gained through activation of genes before birth. With this type of knowledge, an organism is able to react involuntary with an immediate response to a sudden unexpected stimuli, such as a loud sound. This reaction can contribute to the effectiveness and increase the possibilities for an intuitive interaction with an interface.

General knowledge is the next level, gained in early childhood through learned experiences, such as about gravity and concepts for speed. These experiences can help a person to build up image schemas, which are used during its entire life, for interaction with the world. After general knowledge comes cultural knowledge. Different knowledge is gained, even about the most fundamental things, such as differences in the design of doorknobs, and preferred color at funerals, depending on the culture where an individual grows up. The highest level is expertise knowledge, gained through a profession or hobbies. Within general, cultural, and expertise knowledge there is also a knowledge about tools important for the design of an interface. At the cultural level such tools could be cell phones for communication, or ballpoint pens for writing.

The knowledge gets more specific the higher in the knowledge levels you go. One aspect to bring to the design phase of an intuitive interface from the different types of knowledge is in general that the lower in the knowledge levels you stay, the more people may find the design intuitive to use.

3.4.5. How to Design an Intuitive Human-Machine Interface

As seen in previous paragraphs, there is a lot of focus put towards knowledge regarding intuition. So also in the design phase. One way to manage the design process is to strive for a solution where the user's current knowledge point equals the target knowledge point of the interface, so there is no knowledge gap [17]. This stage, where an interface seem intuitive for the user, can be reached through two different conditions, where only one has to be met. The first condition is reached if the current knowledge point is identical with the target knowledge point, so the user's amount of knowledge when first interacting with the interface is exactly what the user needs in order to be able to successfully operate it. To reach this identical point of knowledge, the interface can be designed less complex for reaching a lower target knowledge.

The second condition is if the current knowledge point is separated from the target knowledge point, and the design contributes to bridge the gap without the user being aware of it. In this way, the user is trained to reach a higher current knowledge point in a natural way. Important is that in order to reach intuitive interaction through training like this, the user must not realize it is training. Of course you can also design to lower the gap distance from both directions.

Other areas to deal with in the design phase are function, appearance, and location of a feature [18]. A design with a, for the user, familiar feature allows a quicker and more intuitive interaction compared to a design with an unfamiliar feature. Including familiar features in the design will allow first time users to interact intuitively with the item. For well-known features, familiarity can be transferred from the same area. For less well-known features familiarity can be transferred from other areas by for instance applying symbols from different types of products, or transfer things from the physical world to the virtual world.

A design with an unfamiliar function could leave the user unable to interact intuitively with it, or even unable to interact with it at all. A function should be designed comparable with similar functions or based on processes from features already familiar to the user [17]. Through experiments, Blackler and her research team has found that a feature's appearance enables higher intuitive usability than its location, even though both aspects has relevance [16]. Consequently, it seems important in the design process of an intuitive interface to focus on things such as shape, size, color, and labeling. By getting these aspects right from an intuitive viewpoint, the appearance can help the user to avoid confusion and time wasting. The location should however not be underestimated, since a correct location of a feature can help a user to find it faster. A correct location could for instance be a familiar location, and by choosing such location, response time has been shown to decrease. The same researchers propose that the location of a feature may play a more important role if it gets more standardized on products.

Another area to take in regard during the design process is the aspect of redundancy and consistency [18]. A redundant system that provides different options can allow people to interact intuitively with the same system in different ways. One might interact better with a word, while another might interact better with a symbol. Different users might also prefer to maneuver the same system in different ways. By designing internal consistency, such as building function, appearance and location in a consistent way between different parts within the same interface, users would be able to use the system based on the same knowledge. External consistency will also make the interaction more intuitive [16]. If there is a consistency with things outside the system, the user can more likely transfer knowledge to a new design and interact with it easier and more intuitively.

Finally, the designed system must be able to give appropriate and immediate feedback to its user. It does not matter how intuitively the other aspects are designed if the user does not get a response whether the action was carried out correctly. Uncertainty might lead to interruption of the intuitive flow. The feedback could come from the system itself or through a display.

3.5. INTERACTION POSSIBILITIES

When it comes to interaction with technical interfaces, the user has to be able to provide input to the system and consume output from the system in order for interaction to take place [21]. In vehicles, the interaction between driver and interfaces must occur in a safe manner since safety is of highest prioritization for a driver on the road [22]. With the large amount of technology provided in today's vehicles, the driver-vehicle interface has become more complex. In the regard of designing an interface for an electronic gear shifter, this aspect is important to keep in mind.

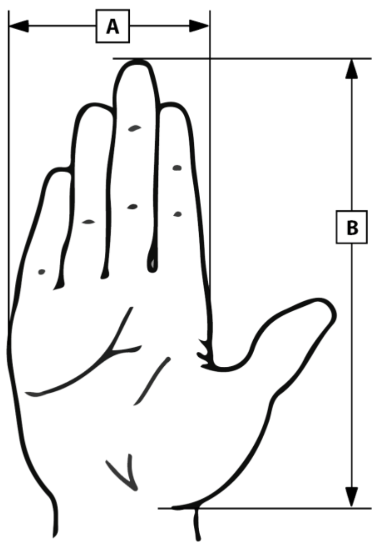
The driver's attention capacity is important to take into account while designing a human-machine interaction (HMI) system [23]. The driver's attention should be on the road and the surrounding environment rather than on the in-vehicle technology. While driving, the appropriate maximum amount of time a driver's eyes should need to look at an interface, such as the stereo or the gear selector, is only one second [13]. During that second, the driver should understand how to maneuver the feature and reach the desired result.

Humans and machines have some common means of interacting with each other. Sight, hearing and touch are the three human senses most frequently used for direct input and output information with a machine [23]. To operate a machine, the human might push buttons or shift controls. Identification through an ID-badge, movement detector and voice command are also frequently used ways to open doors, turn on lights or call somebody, which all can be included in HMI. As a response, the machine may answer by showing the procedure on a screen, making sounds, shifting lights or color on devices, vibrating or changing temperature. These actions all depend on what the machine is supposed to do and what the human tells it to do.

An upcoming technology in cars is brought from smartphones, where touch screens and voice commands has become common knowledge. In present cars, touch screens can be found to control for example navigation and music. Voice commands are also increasingly integrated in the driving experience. Emerging from having a set voice command list, of for example who to call, the user can now speak more naturally to the system. According to MacWorld, Apple's interaction software Siri was installed in a Ferrari in September 2014 [24], and will according to Apple soon be available in a range of cars from brands like Audi, Jeep, Hyundai, Volvo and more [25]. The function is called CarPlay and through the push of a button the driver will be able to take calls, write messages, put in destinations, change music and more, without the need of taking the hands off the steering wheel.

3.6. ANTHROPOMETRY

Anthropometry is an ergonomics genre with the knowledge of human measurements, reach, proportions and similar [23]. A vast collection of data allows a generalized mean value and normal distribution of both body parts and relations between body parts. The standard lengths differ between men and women, but also between humans from different parts of the world. In the automobile industry, little acknowledgement is usually given to the outer percentiles or handicap [13]. However, since comfort still is an important part of the quality perception, the design team will take anthropometric data of hands into account, since the concepts will need to fit the majority of the grown population's hands.



Chosen Measurements [mm]	*Women, 2009 [26]*		*Men, 2009 [26]*	
	Mean	S.D.	Mean	S.D.
A - Hand breadth at metacarpals	78.65	4.48	86.97	5.11
B- Hand length	179.51	8.99	193.80	9.27

Figure 3.5: Anthropometric hand measure points and measuring table [33]

Since gear shifting is a swift maneuver that occurs frequently but not considerably often in an AT vehicle, tension risks will not be evaluated. However, an ergonomic hand posture is desired and a hand position in an extreme angle is downright uncomfortable. The design team will therefore use their ergonomic knowledge to prevent such positions. In figure 3.5 is the mean value and standard deviation of Swedish hand measurements listed, according to Hansen et al. [26], which will also be considered.

3.7. REFLECTIONS OVER THEORY AND MARKET RESEARCH

As the research was conducted, knowledge about SBW, intuition and existing interaction possibilities were built for the design team. This subchapter is presenting the main results found, at relevancy some of the results are linked together, and associations useful in the upcoming idea generation are made. A map of gathered key points is found in figure 3.6 below.

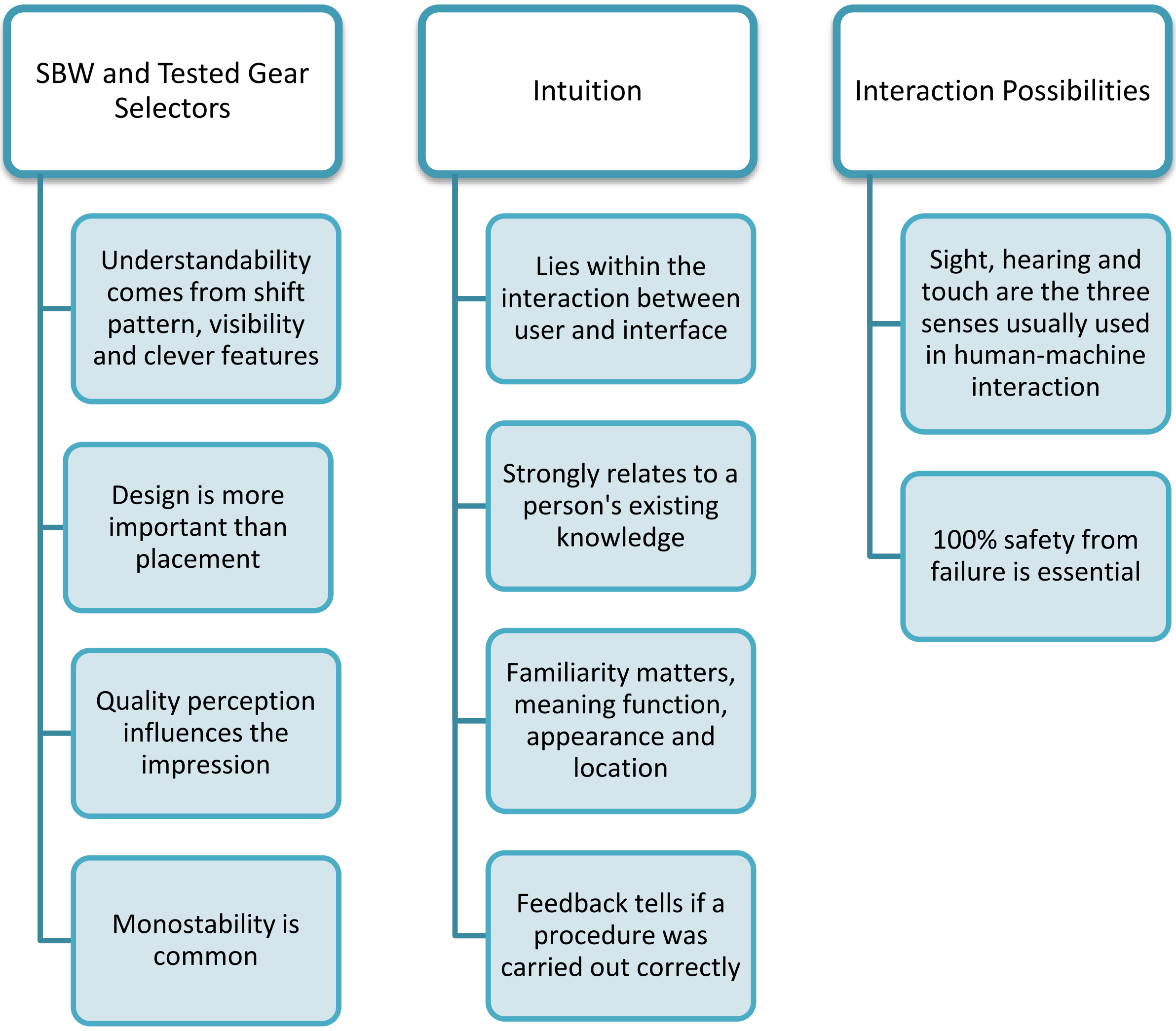


Figure 3.6: Gathered key points from the compliated research

3.7.1. Shift-By-Wire

For the driver, it usually does not matter what kind of gearbox the car has, it is the gear selector that matters. The user might notice that the automatic gear selector is monostable, perhaps requires less force than expected or is moved from its conventional position on the center console. As long as it performs well, much thought will probably not be put into how the gear is operated. Some advantages of SBW is the reduced road noise and fuel consumption.

While testing existing SBW gear selectors, the opinions created for understandability, interaction, quality and placement were described for each car. For instance, the cars where the shift pattern was occasionally disguised were perceived as less understandable than for example the Land Rover's, where the shift pattern is placed in front of the puck and the selected gear is illuminated. In five out of our seven trial systems, the park-mode was a button; Land Rover had it integrated in the rotating shift pattern and Abarth had none. However, only the Toyota's button was separated from the rest of the gear selector, which felt "off". Some of the cars presented a noise when R was selected. This was perceived as a positive indicator, as long as the sound was kept at a decent level and not persistent, otherwise it was stressful.

The gear selectors presented different levels of comfort and quality. For example, the BMW i3 did not encourage the design team to rest a hand on the gear selector, but was still comfortable and easy to understand. The Toyota, on the other hand, encouraged us to rest a hand on the small joystick, even if it was not a comfortable design itself. The expression "eyes on the road and hands on the wheel" implies that the gear selector ought not to take focus from the driving, and should be operable preferably without looking at it. The quality of the gear selector in the two BMWs' and the Mercedes was perceived as better than in Nissan and the Land Rover. Perhaps the manufacturing tolerances were smaller or better designed, which is something we do not intend to discuss further, but the perception of quality is nonetheless mentionable and will be considered.

Regarding the placement of the gear selector, both steering wheel and center console mounted consoles have been evaluated. The conclusion drawn is that the importance is not in where the gear selector is placed, but how it is designed, which correlates with results from the intuition research. The BMW i3 console was easier to manage than the Mercedes lever, even though both were positioned behind the steering wheel. The surrounding area is also taken into account, as for example the Abarth buttons that used an unreasonably big part of the center console.

On the following page, table 3.1 displays the collected information from the test driving.

Table 3.1: Collected information from test driving experience.

Tested cars / Attributes							
	Nissan Leaf	*Toyota Prius*	*BMW 520*	*BMW i3*	*Mercedes Benz B180*	*Land Rover Discovery*	*Abarth 500*
General design	Knob	Small joystick	Joystick	Console	Lever	Puck	Buttons
Placement	Center console`	Upper center console	Center console	Behind steering wheel	Behind steering wheel	Center console	Center console
Functionality (how to access D from P)	Shift sideways, then backwards	Shift sideways, then backwards	Push Unlock-button and shift backwards	Turn frontwards	Pull downwards	Turn clockwise	Push “1”-button
Shift pattern (SP) Understand-ability	- Small SP displayed below the knob - Not clear that the knob should first be moved sideways.	- SP displayed on the joystick clearly shows expected movements	- Backlit SP display on joystick - Confusing “unlock”-button on left side to prevent unplanned gear change	- Easily understood backlit SP on the console - Can get hidden behind steering wheel	- Backlit SP display on lever - Unclear of reaching P by pressing a button, not moving the whole lever - Can get hidden	- Backlit SP above puck - Clearly tells how to maneuver puck to change gear	- Clearly visible big buttons with letters - SP was inconsistent with other systems, using 1 instead of D
Feedback	Selected gear displayed on instrument cluster	- Full interactive SP on instrument cluster, highlighting selected gear - Loud beeping noise in R	- Selected gear is illuminated - Selected gear and operating messages on instrument cluster	Selected gear is illuminated	Interactive SP and selected gear on instrument cluster	- Selected gear is illuminated and also shown on instrument cluster - No stop to prevent accidental gear change	- Beeps twice when changing to R - Current gear is shown on instrument cluster
Quality	Feels small, plastic but cool	Uncomfort-able, but qualitative and appealing interface	Nice, fairly classic, qualitative and clean interface	Comfortable and ergonomically fitted to the hand	Sturdy and good tolerances	Thought-through and metallic touch, but a bit unstable	Plastic, cheap
Other	Felt somehow traditional even with knob-shape	Small and not fully ergonomically fitted	Convention-ally modern	Extra space added to cabin at the center console	Confused for windshield wiper	Simplicity	Unreasonably big surrounding area

3.7.2. Intuition

The intuition research increased the design team's awareness of the importance of knowing what intuition really means in order to design a product or interface to be intuitive. The result shows that it is not the product itself that is intuitive, but the interaction between user and interface that can be intuitive. Hence, the design team should focus on designing a product which users are able to interact intuitively with. Intuitive interaction is also strongly related to previous experienced knowledge. Knowledge gained through previous experiences enables a fast and often non-conscious decision, leading to an intuitive interaction with a product, but it does not happen without a reason.

In the regards of knowledge, it is important to keep in mind that there are different levels of knowledge. The lowest level is innate knowledge, followed by general, cultural, and expertise knowledge. The lower type of knowledge a design requires, the more people may find the design intuitive to interact with. An interface can offer intuitive interaction when the knowledge required for a correct use of the product equals the knowledge the user has when first interacting with the interface. This scenario can be achieved in two ways. Either by designing the interface simple enough, so its knowledge level is in the same level as the user's, or/and by including attributes that increases the user's knowledge level during the first interaction with the interface.

In addition to knowledge, the function, appearance, and location of a feature are important for an intuitive interaction. The word familiarity is strongly associated with these aspects. A function ought to be designed comparable with similar functions or based on processes from features already familiar to the user. When it comes to appearance, things such as shape, size, color and labelling can help the user to avoid confusion. Even a correct location of a feature can help the user find it faster.

When relating these aspects to the design of an intuitive gear selector, the question is if the term familiarity should be related to existing gear shifters, or if it could be related to other familiar features in order to design it most intuitive, and in the same time take advantage of the benefits of a SBW system. Regarding the location, it could be optimal from the familiarity point of view to place the gear selector at the center console where you normally find a traditional gear selector. At the other hand, there might be another location that is more correct. These thoughts will be brought to the generation of ideas and concepts.

The intuition research also shows results about the importance of redundancy, consistency, and feedback. Redundancy in the system might let users interact in different ways with the same system. Internal consistency allows the user to use the same knowledge when using the entire system. External consistency is also of importance, and in the regards of designing a gear selector, that could intend consistency with attributes of other gear selectors and their shift pattern. Finally, only feedback can give information about if an action was correct or not, and is thus significantly important in the aspect of intuitive interaction.

The connection between intuitive interaction, previous knowledge, and familiarity might lock the designers to a commonly existing interface, with the benefit of already including features known to the user. There is nothing wrong with that, but the new solution will probably end up with a design similar to existing gear selectors, and therefore not take advantage of the potential benefits of a new design. This awareness is valuable since it is important for the members of this design team to not get caught in old patterns.

Further facts from the intuition research that will be brought to the design process is that features, location, and the previous experienced knowledge that can lead to intuitive interaction between user and interface does not have to be encountered from the same type of product. The relevant knowledge could be brought by the users past experiences from other circumstances and, in combination with what is perceived by the senses in the interaction with a new interface, can lead to new associations and consequently also an intuitive interaction.

3.7.3. Interaction solutions

HMI traditionally communicates through the three senses sight, hearing and touch. While test driving cars, the team found all three senses being used at some point. Sight was used to understand the gear selector and shift pattern both before and during use, and often also to see on the instrument cluster which gear is selected. For some cars, such as the Toyota Prius, a beeping noise was heard while reversing and in the Land Rover Discovery, the striated sides appealed to the touch sense by giving a better grip and easier understand that the gear selector should be turned.

Safety is of great importance when driving and it is crucial that the gear selector is easily understood and not drawing the attention of the driver. Coincidentally, the group is open for new ways of changing gear but will most likely stick to the three common senses used for HMI feedback in the generation of ideas for gear selector designs.

4. SUSTAINABILITY ANALYSIS

THE SUSTAINABILITY ANALYSIS IS A SHORT CHAPTER DESCRIBING THE ENVIRONMENTAL GOALS FOR THIS PROJECT IN CONNECTION WITH KA´S ENVIRONMENTAL EFFORTS.

There is an increasing focus on sustainable development and environmental issues within product development. Companies have to show customers their environmental accountability in order to be competitive. To guide the employees towards environmental friendly decisions, environmental policies are put together.

Since focus is put towards intuition, a thorough sustainability evaluation is not covered in the scope of this project. However, sustainability is affected through the team’s existing knowledge about how to design a product with a low environmental footprint. Examples of sustainability aspects that will be considered as a natural part of the developing process is the ability of reparation and recycling. The final concept will be assigned with materials durable for its purpose and expressing its intended design characteristics. These decisions are seen as recommendations, and it is up to KA to further evaluate such as material choices before a potential production.

KA is continuously working with sustainability and they have to be industry leaders for being able to sell their ideas to their customers. They are working according to three policies; ISO 14000 standard, their own environmental checklist for design, and International Material Data System (IMDS) reporting. ISO 14000 is an environmental tool to tackle environmental issues such as climate change and pollution on a global scale [27]. With help of the tools provided in the ISO standards, KA can control their environmental impact and improve their environmental performance. The standards in the ISO 14000 family focus on environmental management systems, as well as more specific environmental aspects such as life cycle analysis. KA’s environmental checklist for design is a company document with 19 questions concerning the subjects weight, product, production process, and environmental quality assurance [28]. IMDS is the material data system connected to the automobile industry, where all material used are collected, maintained, analyzed and archived [29]. It is used by almost all of the global original equipment manufacturers and has become a global standard that helps automobile manufacturers and suppliers to meet their obligations set by standards, laws and regulations, both nationally and internationally.

Even though the design team will suggest materials for their presented concept, they trust KA in the regards of controlling final material choices and environmental decisions towards their thorough environmental efforts. That way, the design team’s focus is put towards what is important for finding a concept whose function and design is perceived as highly intuitive.

5. IDEA & CONCEPT DEVELOPMENT PROCESS

THIS CHAPTER COVERS THE PROCESS FROM THE INITIAL IDEA GENERATION TO REACHING NINE IDEA CONCEPTS.

The knowledge gained through research builds the foundation for the idea generating process. This foundation will serve as a guideline and give directions to the forthcoming work without putting up any fences for reaching a creative solution. In the iterative developing process, methods of ideation will be used to form a variety of ideas. First, ideas will stay uncriticized, and later ideas with low potential will be eliminated or changed and ideas with higher potential will be further developed in the concept generation phase. The ideas will be objectively criticized and reduced to first three then one final concept. The process is shown in the funnel diagram, see figure 5.1.

Since the aim of this project is to design an intuitive gear selector for a SBW system, there are possibilities to design it without many of the limitations that gear shifters was originally limited to. The design can thus significantly differ from what is on the market today. There is a challenge within redesigning a well-established global product integrated in a huge part of the world population’s lives. Drivers used to a traditional AT might see a barrier in using a different design intuitively. During the

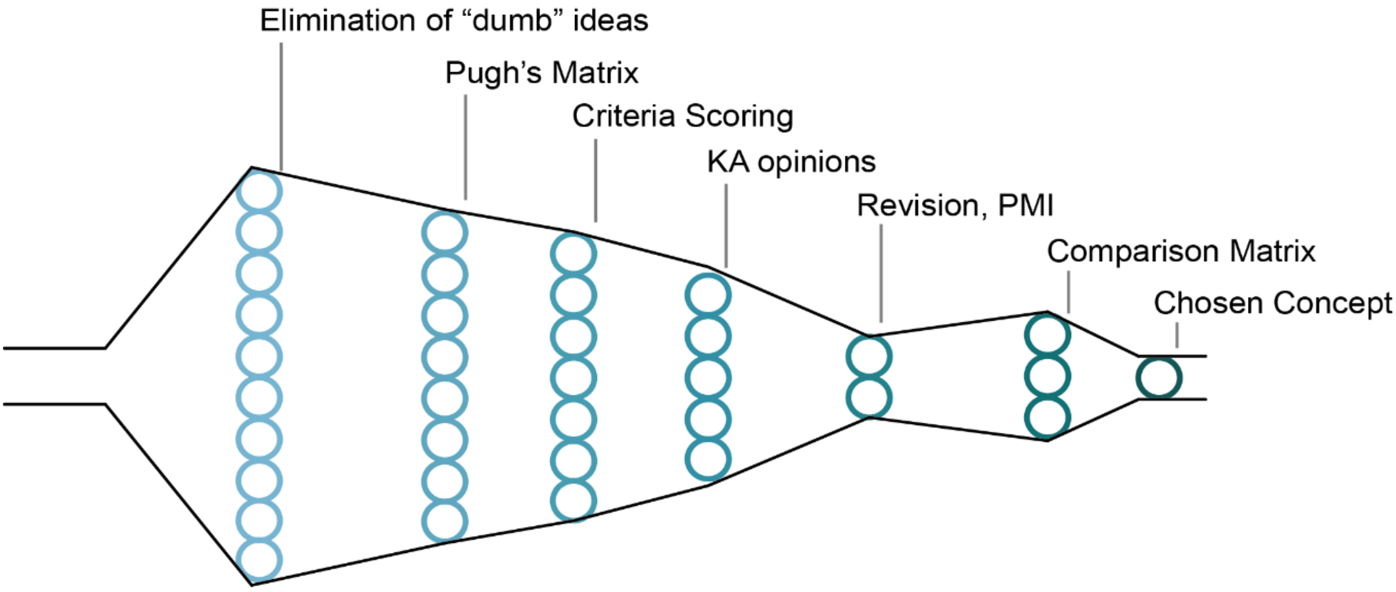


Figure 5.1: The funnel of product development [1], accustomed to this project

idea generation the design team will keep this in mind and aim to design an interface with a low learning curve that is perceived as intuitive even though it might not look like a traditional gear shifter. This would prevent the team from being stuck in patterns and limitations that were set a long time ago and during other circumstances.

One thing to keep in mind during the concept development is that there is no specific car type or projected user set to the final concept. This means that the concept has to be eligible for any kind of car from any brand, and for any kind of customer. The driver could be anyone, from someone who practices driving to an elderly person who has had a driver's license for many years, and also people from any part of the world with any length and body shape, people owning their own car or renting one. The solution shall also be suitable for an AT, but KA cannot choose which type that will be used. Therefore, the solution has to be suitable for both AT, AMT, CVT, and DCT, which are the four options of automatic transmissions, mentioned in the research of SBW.

5.1. REQUIREMENT SPECIFICATION

The design team has based the criteria of the requirement specification, see table 5.1, upon the results of the precedent research and relevant paragraphs from the laws FMVSS 102 and FMVSS 114 (see appendix 2 and [12, 30]). In the requirement specification, the laws are interpreted to make them easier to understand and use in the product development process. The requirement descriptions marked with a star (*) are interpretations of the laws, and the reference column shows which law and paragraph is being used. When doing further research after this project, the actual laws should be regarded, and not the design team's interpretations. Only the laws related to the scope of the project is taken in regard.

The specification is subdivided in the four categories. The first category provides requirements regarding position and shift pattern, based on the relevant paragraphs from concerned laws. The second category offers requirements about usability and is based on interaction research, the team's benchmarking analysis and facts given from Jimmy Östman, the team's advisor at KA. The requirements in category three comes from the intuition research and describes what should be consider in the regards of offering an end product with potential for intuitive interaction. The last category shows which environmental commitments that should be regarded, and comes from the sustainability analysis. Obvious criteria, such as *shall fit in the driver interior*, is not mentioned in this requirement specification.

Table 5.1: Requiremet specification of an intuitive AT gear selector

Requirement Specification *Intuitive Shift-by-Wire Gear Selector*			
Req. No.	***Requirement Description***	***Reference***	***Priority***
1	Position and Shift Pattern		
1.1	A neutral position shall be located between forward drive and reverse drive positions *	FMVSS 102 S3.1.1	Require
1.2	If steering-column-mounted: movement from neutral position to forward drive position shall be clockwise *	FVMSS 102 S3.1.1.1	Require
1.3	If Park position is in the shift pattern: it shall be located at the end, next to the reverse drive position *	FMVSS 102 S3.1.1.1	Require
1.4	The complete shift pattern should be visible to the driver at a single location whenever the vehicle is operable *	FMVSS 102 S3.1.4	Require
1.5	The selected gear may be visible to the driver at an additional location.* *(Either separately or with the shift pattern)*	FMVSS 102 S3.1.4.4	Desire
1.6	If the vehicle is equipped with a "park" position, the service brake must be depressed before transmission can be shifted out of "park" *	FMVSS 114 S5.3	Require
1.7	The shift pattern should always be in the driver's field of view *(should never be hidden for the driver behind other features)*	SBW research	Desire
2	Usability (for manufacturer and user)		
2.1	The gear selector solution should be applicable to any kind of automatic gearboxes *(AT, AMT, DCT, CVT)*	J. Östman	Require
2.2	The interface should be easily understood by the user	Interaction research	Require
2.3	The interface should not draw the driver's attention from the road *(maximum 1 second of the attention should be enough guide the user)*	J. Östman	Desire
2.4	The final concept should be perceived as qualitative *(both haptic and visually)*	Benchmarking	Desire
3	Intuitive interaction		
3.1	The user shall be able to interact intuitively with the gear selector	Intuition research	Require
3.2	The knowledge necessary for a correct use of the gear selecting device shall equal the user's current knowledge level. *(either by an interface simple enough, or by attributes increasing the users' knowledge level)*	Intuition research	Require
3.3	The design of the gear selector relates to the user's existing gear changing knowledge *(such as knowledge gained through previous experience with gear selectors)*	Intuition research	Desire
3.4	The system shall provide features already familiar to the user *(such as, but not limited to, R, N, D and P selections)*	Intuition research	Desire
3.5	Redundancy may be provided through different ways of interaction *(if so, the different ways should provide the same result)*	Intuition research	Desire
3.6	Internal consistency should be provided to allow the user to use the same knowledge when using the entire system	Intuition research	Require
3.7	Feedback shall provide information about if an action was correct or not	Intuition research	Desire
4	Environmental Commitments		
4.1	The product shall be repairable by after-sales departments	Sustainability Analysis	Desire
4.2	The product shall meet the vehicle industry's demand of recycling	Sustainability Analysis	Require

5.2. THE IDEA GENERATING PROCESS

The idea generating process is the first creative step towards the final concept. The goal is to create idea concepts with potential of becoming a gear selector in an actual car. With the benefits of SBW, the design possibilities are close to endless, so focus in this project is set towards making the HMI as intuitive as possible. The design team integrates the knowledge learned through the research with knowledge of ergonomic and design interaction possessed through their Design Engineering education.

The generating of ideas was conducted through benchmarking, random words and idea playing cards, all used together with free sketching. To help the ideas along, a placement evaluation was conducted. The placement evaluation helped the design team to focus on a solution fitted for a specific surface or position. The suggested positions can be seen in figure 5.2. Since SBW gear shifting is transmitted electronically, any placement is possible. To broaden the spectrum, locations in the roof and next to the pedals has been considered, but was ruled out due to their inconvenience. The five placements taken into consideration when designing concepts are marked with a circle.

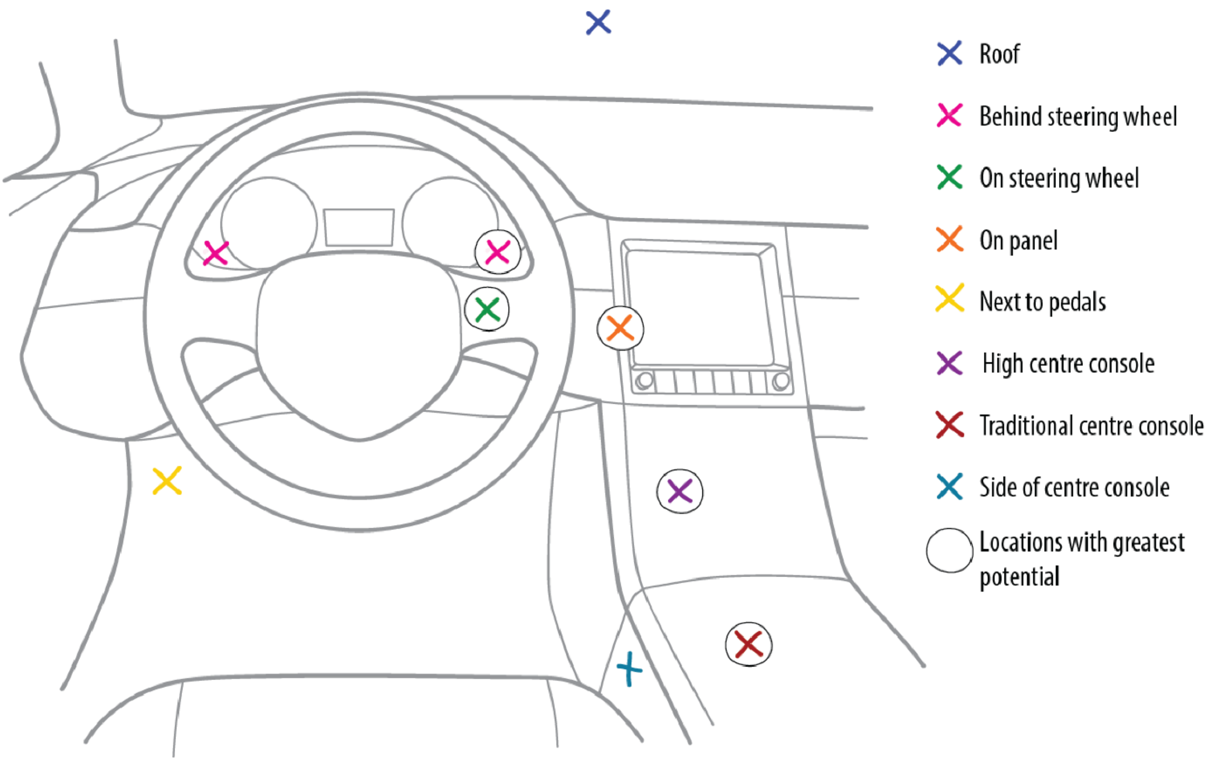


Figure 5.2: Suggested positions of gear selectors in car interior

When the design team had come up with some shapes and concepts, they called in a brainstorming session to see if others could have solutions that the team had overlooked or not thought of. The design team invited 16 young adults, explained the task and asked them to discuss and draw their solutions for gear change on a large piece of paper. The group consisted of soon-to-be engineers in the field of automation, embedded systems, design, civil and chemistry, a bus driver, a teacher and a translator with online racing interests. Surprisingly, the design team had already discussed most of the realistic ideas that this brainstorming session resulted in. This is not saying that there are no other solutions for how to change gear, but perhaps the solution is more dependable on the design than the actual function of gear change.

As the ideation carried on, idea concepts started to take shape. A compilation of early ideas are found in figure 5.3 below. A first draft of different concepts, displayed in sketches, were discussed with the design team’s supervisor at Chalmers, Johan Heinerud. With the help of his comments and advice on how to refine and further develop the idea concepts, the group eliminated some of them due to lack of potential within the ideas, and began developing the remaining nine further. Every idea concept was thoroughly discussed, and in some cases changes were made.

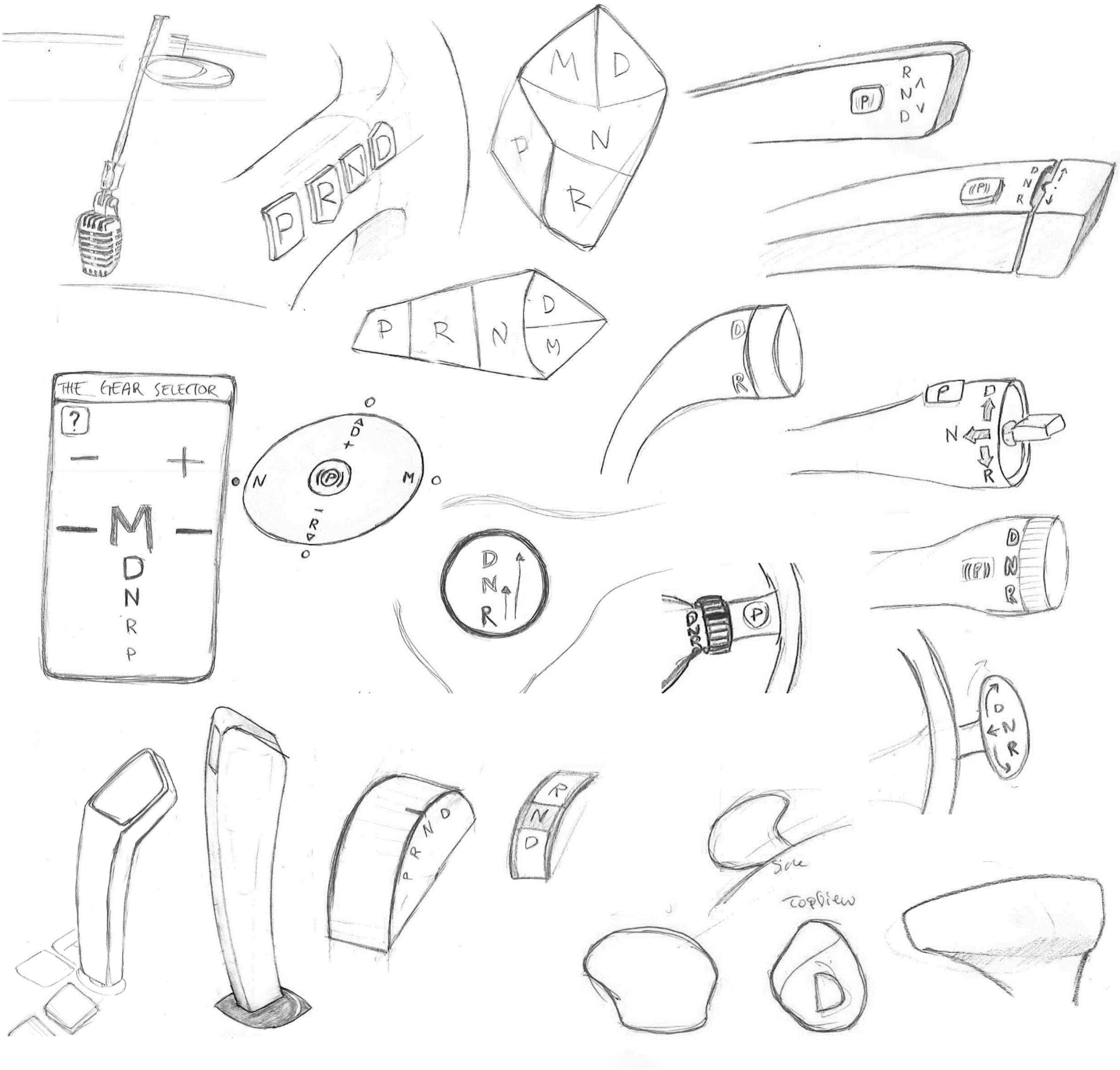


Figure 5.3: Collection of early ideas and sketches from the ideation process

5.3. IDEA CONCEPTS

The ideas gathered during the ideation was put together and the design team created nine idea concepts. The sketches were refined and digitalized in Adobe Photoshop and Adobe Illustrator. The concepts were digitally drawn both to be better apprehended by the design team and to lead an easier presentation and discussion with KA, as a stage in the elimination process.

Each of the idea concepts may have the capacity to become a finished concept after further development, but more importantly, they are still adaptable for changes. When validating them, it is important to keep in mind that they are still in an idea stage and the idea concepts with greatest potential will be taken to further development. The material, color and, in some cases, shift pattern that the idea concepts have been provided with may be adaptable to other interior details.

There are some attributes that are common for all or most of the concepts, developed from results of the initial research. The common attributes are listed in table 5.2 below, but are first explained in greater detail. All of the idea concepts have a gear selection for reverse propulsion, neutral mode, and for forward propulsion. These are called R, N, and D, since they are symbols already well established in the world of AT. The focus is put towards these three gears but despite this, the design team is not excluding another forward propulsion gear option, such as M, B or S, etc.

The P for park position and the P for handbrake are in several concepts combined since they have the same function for the driver, even though they have different functions within the car. The design team is aware that this might be a threshold for the automotive industry to cross, but it may offer a more intuitive interaction with the driver when fewer functions are available. In three of the concepts there is an engine start and stop button included. The main reason for this is that it might not be obvious for a new user to directly find a non-traditional gear selector at a non-traditional location. Before changing gear the user has to start the engine, and if these functions are located next to each other they could both be found at the same time.

Another common attribute for the concepts is that their shift patterns are all illuminated. This is because the design team claims that such shift pattern provides the user with an easy glance of the gear options and may reduce any potential knowledge gap. Thereby, a greater deal of intuitive interaction can be provided to a broader user group. The idea concepts offer different types of feedback to show the user what gear is selected, often in two interacting ways to provide redundancy. The selected gear is also clearly indicated at the instrument cluster and is in several concepts connected to an interactive shift pattern. This should provide the driver with a better overview of the chosen propulsion direction and the possible gear options. The idea concepts will now be presented by a short description as well as their digitally drawn sketches. The full posters made for presenting the idea concepts can be seen in appendix 3.

Table 5.2: Common attributes of idea concepts

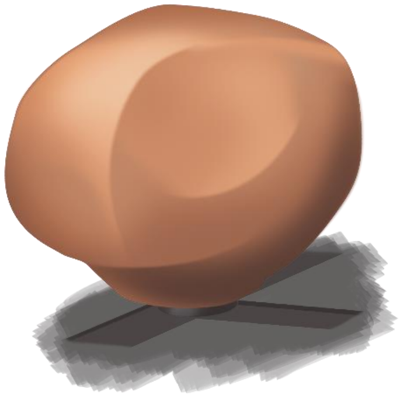
Common Attributes:

- ✓ R, N and D are integrated in all idea concepts
- ✓ Shift pattern is illuminated
- ✓ Selected gear shines brighter/stronger
- ✓ The selected gear and possible gear options (if applicable) are shown in the instrument cluster

5.3.1. Flipswitch

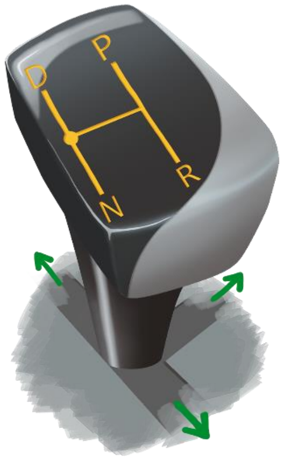
Flipswitch is a sleek monostable joystick with an integrated touch screen on the top surface, placed at the left side of the center console. The driver can use either the joystick function or the touch function. The touch is activated by pushing the "touch on" button by the foot of the joystick. When the touch is activated, the joystick only works with a great amount of force, with the aim to still be durable in a panic situation but avoiding unintentional use of the two options simultaneously. The shift pattern is the same for the joystick function as for the touch function. To change gear in touch mode, simply swipe a finger in the desired direction. Feedback is given by enlarged letter for the chosen gear and two beeps when accessing R.

5.3.2. Potato



When designing this idea concept the design team aimed to provide a concept that delivers a feeling of organic sturdiness in an ergonomic shape. Therefore, Potato is shaped for the hand to rest comfortably, and is given ceramics as preferred material, which not only offers an organic feeling but also an outside the box thinking within the automotive industry's material bank. It is preferably placed a little higher on the center console. The multistable shift pattern is designed to be associated with the movements of a manual gear shifter, providing a sturdy feeling and create connections to the muscle memory, in similarity with a stick shifter. Feedback is given by enlightened gear letter on the center console and gentle vibrations from the knob. Potato gives one long vibration for forward propulsion, and two short for backward propulsion.

5.3.3. Soft Cube



With Soft Cube, focus has been put on the shift pattern with the aim of designing a gear selector that correlates to the user's muscle memory in a similar manner as a traditional manual stick shifter. The design is comfortable and classic, a monostable lever with a smooth top display, brushed details and a distinct track as shift pattern, which is also visualized on top of the product. The lever itself is designed to offer the driver a good grip and is placed on the center console between the front seats. Feedback is given through enlightened letter for the chosen gear and vibration, one long for forward propulsion and two short for backward propulsion.

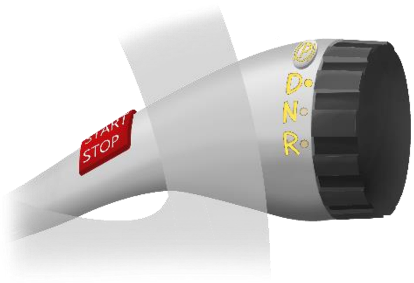
5.3.4. Touch It

This diamond shaped touch display framed in brushed silver is based on touch technology with an integrated click function. It can be placed on the center console, advantageously slightly angled towards the driver. The entire shift pattern is shown on the screen with the chosen gear enlarged in the center, framed by two arrows. To change gear, the driver swipes the screen similarly to a smartphone's screen, and selects gear by tapping on the screen when the desired gear is placed between the arrows. Only one gear can be moved per swipe. Feedback for a successful gear change is given by the clicking sound as well as that the active gear's letter gets a brighter color in the shift pattern. The screen is also providing a smart question mark, which blinks when information might be needed. If the driver clicks it, it will provide beneficial information.

5.3.5. Scroll Pad

Scroll Pad has a curved surface inspired of a conveyor or travellator. It has one fixed part to the left where the shift pattern is found, and next to it a grip friendly movable part that the driver scrolls forward or backward in order to change gear. When scrolling to a new gear there is a slight resistance which gives a haptic feedback. The selected gear's letter shines brighter, together with a small bar pointing towards the movable part. Scroll Pad can be placed at various locations on the center console, with advantage slightly angled towards the driver.

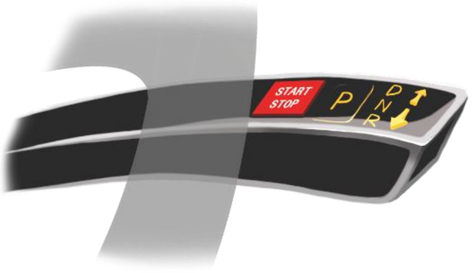
5.3.6. Turning Console



Turning Console is a tapered cylinder shaped gear selector. It is placed behind and extending outside the steering wheel, and above a potential windshield wiper lever. It has one fixed part where you find the always visible shift pattern as well as the engine start and stop button. It also has one movable part in a grip friendly material which the driver turns for selecting gear. It is multistable and when changing gear, a slight resistance is applied so the user senses that another gear is being selected. A light indicator next to the gear's letter indicates the chosen gear.

5.3.7. Bridge

Bridge is a monostable gear shifter placed behind the steering wheel with an accentuated design to differ it from, for instance, a windshield wiper lever that is often found at a similar location. It extends outside the steering wheel so its shift pattern will always be visible for the driver. To switch gear, the lever is pushed with a small resistance forward for D and backwards for R, with N in between, indicated by the shift pattern as well as by arrows. Selected gear shines brighter, and a gentle sound will indicate when R is selected. P is provided by a button on the lever, outside the shift pattern and next to the engine start and stop button. These buttons are visible behind the steering wheel when looking slightly from the right.



5.3.8. Cogwheel

Cogwheel is an idea concept found on the steering wheel's spoke. It is designed with cogwheel characteristics, with a part of it emerging from the steering wheel. The user turns it up or down for changing gear preferably with the thumb. The system also has a voice command available through the push of a button to the right of the cogwheel. When using it, press down the button and say, for example, "reverse". Feedback is received both visually and audible; the selected gear's letter lights up and one smooth signal indicates that D is chosen, while two short signals indicate that R is chosen. The cogwheel itself is made of a see through material, lit up to be easily seen and the outgoing cogs has a grip friendly material, such as rubber. P is separated from the shift pattern and placed on a button next to it. The cogwheel is monostable, and you feel the gear changing in the turning movement through a slight resistance.

5.3.9. Shield

Shield is a platform with brushed cold-touch buttons, also placed on the steering wheel spoke. The placement provides an easy overview, but Shield can also be given another position, such as the higher positions of the center console. The shape of the buttons shall make it possible for the driver to feel which button provides which gear, and thus enable gear change without looking. The selected gear's button stays pressed as long as the gear is selected, and glows by the edges. The engine start and stop button is integrated in the platform, but is distinguished by having another color, material and surface. However, the text is illuminated, just as the gear letters.

6. FIRST CONCEPT ELIMINATION

IN THE FOLLOWING CHAPTER, THE CONCEPTS ARE EVALUATED
AND PUT THROUGH AN INITIAL ELIMINATION.

Some of the concepts generated in the idea generation process must be eliminated in order to end up with one final concept. This elimination is made objectively through three channels. First by a visit to KA to present and discuss the idea concepts, where they are asked to individually rank concepts with high potential. Second, by Pugh's decision matrix to strategically evaluate each concept and thirdly, by using a criteria scoring matrix conducted to rank the remaining idea concepts through different criteria. The two decision matrixes weigh as heavily as the thoughts of KA, and the aim is to have a maximum of three idea concepts to develop further before making the final concept decision.

The choice of limiting the idea concepts from nine to three before narrowing it down to one is an obvious decision for the design team. Going straight from nine concepts to one is in this process perceived as unrealistic, since the nine concepts are not fully developed and a lot of potential within the eliminated concepts might be lost on the way. Therefore, the three idea concepts remaining after the first steps of elimination, will be revised and further developed.

6.1. COMMENTS FROM KONGSBERG AUTOMOTIVE

When the concepts are prepared, the design team visits KA to hear their comments. The concepts are presented and discussed with a group of ten employees working daily with gear shifters. Each idea is presented on an A3 poster with pictures explaining the concept and the interior placement as well as a describing text, see appendix 3. The goal for the presentation and discussion is to hear which three concepts KA believes have the highest potential.

The presentation at KA resulted in a good discussion about the concepts. It received compliments for being well performed with great sketches of the concepts and an impressively good understanding for the topic. The co-workers found it was interesting to see that the design team had reached some similar results and reasonings as KA have, and exciting with some completely new ideas. The design team found the discussion with KA very valuable, and will consider some of their thoughts both during the elimination process and later on in the further concept development. The comments are therefore thoroughly presented in this subchapter, first with general comments concerning all or most of the concepts, followed by comments specific to each concept. At the end there is a diagram showing how the concepts were ranked by the KA co-workers, which will be used in the concept elimination process.

6.1.1. General comments

Some concepts were presented with a combined P for park position and handbrake. The KA representatives said they have thought about this as well, and it brought a discussion regarding existing electronic handbrakes and their intuitive problems. A traditional mechanical handbrake serves as an additional brake if the service brake stops working, but the modern electronically monitored handbrakes do not serve the same purpose since they cannot be applied without power. With this in mind, the integrated park-handbrake feature may be an operable solution.

In regards of monostability versus multistability, some interesting comments were made. Most SBW systems are monostable, but the KA representatives had a positive reaction towards multistability within some of the concepts. Letting the selector stay at the chosen gear's location gives a more distinct feedback than if it always returns to the monostability point. The HMI interaction gets the same effect no matter which stability point, but there are some differences when developing the different systems. If the system has dedicated positions for each gear, considerations about lockups must be regarded.

Feedback was also generally discussed. Enlightened letter for chosen gear was seen positively, especially in combination with an enlightened arrow or similar. Sound, such as similar to the beeping signal for reversing with a truck, can be good and clarifying but some people can find it disturbing. Only acknowledgment sound is not enough for the ones with bad hearing though, and with a global aging population this is important to keep in mind. Vibrational feedback could be tricky and one can interpret it as something negative, such as doing wrong. At the other side, a mobile phone that vibrates when receiving a text message usually provides positive feedback to its owner.

Flipswitch

The overall impression of Flipswitch was positive, where the combination of a haptic joystick and a touch function was seen as an interesting transition towards touch technology within gear selecting. A pure touch screen could be a too big leap, but this combination seems like a feasible and implementable solution; a fair step in the strive of new technology with the possibility of being easily understood. Someone was a little bit skeptical about the opportunity of being able to interact with the gear selector in two ways, but it seemed positive not being able to use both shifting possibilities simultaneously.

A clearer indication of where in the shift pattern the user is was desired, but good that the chosen gear's letter becomes bigger. Further development of the touch screen was also desired. One suggestion was to use the touch only for secondary functions, such as transmission mode (A, M or B etc.), park and neutral, and then always use the joystick for controlling the car's propulsion direction. Another suggestion was to make the touch system more like Touch It's, where you have to both swipe then tap for selecting gear.

Potato

Potato also contributed to a positive impression on the KA co-workers and its totality was perceived as "super interesting". Its aesthetics, especially its suggested material, was commented upon most frequently where the idea of using a different material and creating new shapes was welcomed. The material choice of ceramics was found interesting and exciting, especially in visible details. A discussion about whether giving this material to the whole knob or just to its surface occurred, where both options seemed possible. One of the co-workers said that a ceramic coating already exists within the automotive industry as an additional option that BMW uses for creating a cold-touch surface.

The shift pattern also caused a great deal of discussion. The structure, inspired from a manual gear shifter, provides the user with haptic movements allowing one to learn the positions, and thereby quickly be able to change gear without looking at the gear selector. In the same manner, its multistability was also seen positively. A comparison was made with Toyota Prius' monostable gear selector, where it is tricky to know what gear one has put in, since it moves back to its original position after gear changing.

Someone thought that providing the shift pattern with an engine brake, B, seemed to make sense. The B might not be as implemented as D, but the idea behind it is great for avoiding overheated brakes. Seen as a downhill mode, this might be found more intuitive than a manual mode, which someone also commented as just being silly in an automatic car as long as there is nothing wrong with the product. In an electric car, a mode such as B could offer generation of electricity. An option would be that the car itself figures out when this function would be needed, and takes care of it automatically in D mode.

Soft Cube

As the third concept placed on the center console, Soft Cube also gets overall positive response and is seen as a feasible and easily understood solution. One comment about its aesthetics was that a golf enthusiast would buy it straight away, and KA co-workers seemed to like the general design. In this concept, they mainly liked the shift pattern, of the same reasons they liked Potato's shift pattern. Multistability was also here seen as more positive than monostability, because it feels sturdier to move a lever that stays in its gear position. One of the co-workers misses the M-mode's ability to lock the chosen gear, for instance when driving in the mountains, and thus utilize the effect of engine brake so the car does not gear when its speed changes in downhill hairpin curves.

The shift pattern shown in the instrument cluster was also perceived positively because it should let you see and understand the shifting options and your current gear position easily. Ideas from Soft Cubes interactive shift pattern could be brought to Potato. One suggestion for further development is to "move" P depending on if P is selected or not. If P is selected, the P should be located between D and N, and if P is not selected it should be located in the right upper corner. This to make it more clear how to move the lever if it is monostable.

Touch It

Touch It got both positive and negative response from KA. They thought it was an interesting concept, but mainly in the regard of future thinking. It has a stylish and understandable display but the gear options furthest away are so small and might be hard to see. They understand why the letters are changing size, but they might not need to be that small. They are positive to the gear selections dual sequence; to first swipe one gear per swipe, and then tapping the screen to make the gear change happen, that would reduce the risk of an accidental gear change. Despite this, they still see a potential risk of incorrect use among elderly who may not be familiar enough with the touch technology. They might for instance accidentally swipe when they are supposed to tap and thus access wrong gear.

For a haptic feedback, they thought the collapsing feeling provided when tapping seems smart, so the user knows that the tap was correctly implemented. Other than that, touch systems lack the feeling of control one can get of a more physical gear selector, which could make them hard to implement today. Touch systems are hard to maneuver without looking at, and Touch It requires the user to look at the shift pattern for making sure that the right gear is selected. This will take focus from the road and the driving.

The idea of the smart question mark providing information when needed was strongly criticized as not being intuitive at all, that something is wrong with the system if that is needed. If you overlook the question mark, the idea of information messages might be good. When you're not able to change gear, the message can tell you what to do and in the same way block the gear selector, with text such as "push the brake" if that is required. Touch It's placement could negatively require the user to lean a little forward to reach it, perhaps it could be placed somewhere else such as in the center of the steering wheel. Other comments was that the lack of mechanical parts was not for an advantage for KA, and when developing systems like this, there are other things to take in account, such as not being sued by Apple for using something that reminds of their features. Finally, for being a touch system, KA thought it has potential, and one idea might be to bring attributes from this concept to Flipswitch's touch screen.

Scroll Pad

Scroll Pad was seen as a feasible solution with potential of being easily understood. The shape of the moveable part's ribbon patterned band indicates that you should scroll it, and provides a perfect understanding about how to use it. Someone asked about how grip friendly the material is, if you can use it with gloves, and if the surface is sleek or has actual ribbons. Another comment of the moveable part was that it reminds of a jalousie-like tray today found in some of Volvo's models. It would be preferable if the band went all the way around and was software controlled, not mechanically.

The concept and it's placement was by the KA employees seen as a new grip of rotational controls that could be space efficient, but its current look feels a bit old-fashioned. Questions were asked regarding the user experience and the maneuvering of the product. For changing gear, can you just scroll, or should you push and scroll? Does it offer fixed gear positions, or can you scroll it without a successful gear change? Is any gear locked so the brake needs to be pressed in order to change gear? The manual mode could be changed to another transmission mode. Finally, they nodded regarding the resistance that provides a haptic feedback when changing gear and said connections to the muscle memory and haptic feedback is a good idea.

Turning Console

Most of the comments regarding Turning Console were about its location. It was perceived as a great location since it behind the steering wheel is "out of the way" and offers space to other features that normally compete for the center console area, such as cup holders. It was however perceived as being difficult to operate because it might be hard to see and reach. If this becomes a relevant concept though, the gear selector should follow the steering wheel when one adjusts its position. The integrated engine start and stop button was found interesting. P could be either a button or integrated in the shift pattern. Having an arrow or similar, such as the lamp in this concept, pointing at the chosen gear is a good and distinct feedback. Perhaps an indication could be located in the moveable part instead, if it is multistable.

Bridge

Since Bridge has a similar location as Turning Console, some of the comments are the same. The location could be advantageous in the regard of not competing for space, but might be difficult to maneuver because it might be hard to see. For this concept, there is also a risk of a long driver to push the gear selector with its knee because of its low placement, and it might break. The integrated engine start and stop button was thought to be interesting, and it seems like a good thing that this button and the P button next to it are designed with different surfaces.

There was also some confusion connected to the presentation of this concept. Someone thought it was very strange that the primary movement was not consistent with the steering wheel's turning movement, and expected to move it upwards and downwards as the other levers around the steering wheel. One suggestion was to make the design more inviting for a forward, backward movement.

Some misjudged how the buttons shall be pushed compared to how the lever shall be moved, and thought that the lever was going to move as a consequence of pushing the buttons. The shift pattern was not completely clear either, one question was asked whether D was accessed by pushing the start button, and one whether you go from R to D in one or two movements. It was seen as important that the display is always visible, and one suggestion was made to move it to the side to see it better. The sketches of this concept might have been a little misinterpreted, but the overall picture was that this is not a very intuitive concept.

Cogwheel

When presenting Cogwheel for the KA representatives, one association was made with BMW that has a similar feature on the steering wheel for controlling the radio, which was seen as a very clever solution. Besides that, the criticism was not that positive. One comment was that steering wheel mounted gear selectors do "not feel that hot," and the concept was in general seen as hard to maneuver.

Cogwheel's biggest problem and disadvantage is that it follows the steering wheel when turning, which results in that the interface may be upside down, so you might not know where it is or how to maneuver it. This is an existing problem for some features already located at the steering wheel, such as the phone control. This was seen as a big problem both for the reason that changing gear is a primary function, and because that you often want to change propulsion direction quickly and easily during precision driving, such as parking, where you also normally use large steering wheel rotations. It is preferable to have the gear selector at the same location at all times, and this might be the reason for why we have not seen a gear selector placed on the steering wheel yet. One suggestion for overcoming this problem was to place it further towards the steering wheel's center and use a two-pieced steering wheel, but that makes it more complicated. Other struggles with the steering wheel location could be that other features already often occupy this place, it could be too easy to access it by mistake, and in a panic situation, you might squeeze the steering wheel and thereby jeopardize an unintended gearshift.

The button for voice command was seen as a good complement when the steering wheel turns, but someone asked if it is necessary to have both the voice command and the wheel. If you realize that the voice function exists, it seems pretty safe, especially if you have to keep the button pushed while giving the voice command.

Shield

Since shield is also located at the steering wheel, much of its critique was the same as for Cogwheel. The problems seen with for instance large steering wheel rotations, and the fact that the time for the presentation was running out, meant that the co-workers hardly commented the concept in general. One question was asked, whether it was actual physical buttons, and we briefly discussed whether the same gear selector could be placed at a different location within the interior.

6.2. COLLECTED MATRIX FOR KA CO-WORKERS COMMENTS

The KA co-workers who attended the presentation was asked to rank the three concepts they believed to the highest potential. Out of ten attendees, seven left comments by email. Their votes are displayed in table 6.1, both with consideration of which order they were mentioned and just put together, since it was not always clear if the concepts were ranked or simply lined up.

Table 6.1: Ranking from co-workers of KA on the nine idea concepts

Concept / Criteria	*Flip-switch*	*Potato*	*Soft Cube*	*Touch It*	*Scroll Pad*	*Turning Console*	*Bridge*	*Cog-wheel*	*Shield*
Ranked 1 (3p)	III	I	I	-	I	-	I	-	-
Ranked 2 (2p)	I	II	I	II	I	I	-	-	-
Ranked 3 (1p)	I	-	IIII	-	I	I	-	-	-
Points Total	12	7	9	4	6	3	3	0	0
Total No. of votes	𝍸	III	𝍸 I	II	III	III	I	-	-

6.3. PUGH´S WEIGHTED DECISION MATRIX

When using Pugh’s weighted decision matrix, each concept is graded to be a better, same or worse solution than a market standard on different criteria [1]. The market standard is decided to be the gear selector in BMW 520, tested in the field study. The design team found it to be the one most similar to a mechanical AT gear lever, both in regards of interface and shift pattern. It also seems suitable, since the design team aims to design a gear selector better than the SBW solutions existing at the market today.

The result is seen in table 6.2 on the next side, where the listed criteria are taken from the results of the theory and market research, and are here given a short explanation:

- **Accessibility** – to be available for the driver at a convenient location at all times.
- **Uniqueness** – positive if the concept’s general design differs from the common mass of existing solutions.
- **Ergonomic** – is it comfortable to maneuver and reach?
- **Intuitive interaction** – does the interface have capacity to offer intuitive interaction? May the user instantly understand that it is the gear selector, and how to maneuver it?
- **Shift pattern understandability -** can the user understand how to shift gear straight away?
- **Interactive display** – how well is it showing the user the chosen gear and the gear options? On instrument cluster or on device.
- **Feedback** – does the user get notice about if an action was carried out correctly through haptic, sound or vision? Feedback in at least two ways is preferred.

The points total is calculated by first summing up how many weighted plus and minus points each concept has, and then calculate the total point for each concept.

Table 6.2: Pugh's Weighted Decision Matrix for initial concept evaluation

Criteria \ Concept	*Weight factor*	*Ref. BMW*	*Flip-switch*	*Potato*	*Soft Cube*	*Touch It*	*Scroll Pad*	*Turning Console*	*Bridge*	*Cog-wheel*	*Shield*
Accessibility	3	0	0	0	0	0	0	+1	+1	-1	-1
Uniqueness	1	0	+1	+1	-1	+1	+1	+1	+1	+1	+1
Ergonomic	2	0	0	+1	+1	-1	+1	+1	-1	-1	0
Intuitive Interaction	5	0	+1	+1	+1	-1	+1	+1	+1	-1	-1
Shift pattern understandability	4	0	+1	+1	+1	+1	+1	+1	0	-1	0
Interactive display	3	0	+1	+1	+1	0	0	0	+1	0	0
Feedback	4	0	+1	+1	+1	+1	+1	0	+1	+1	+1
Sum of +1		-	+17	+19	+18	+9	+16	+15	+16	+5	+5
Sum of -1		-	0	0	-1	-7	0	0	-2	-14	-8
Points Total		-	17	19	17	2	16	15	14	-9	-3

As seen in the matrix, seven concepts, marked in green, received higher points than zero, and are therefore moved on to the criteria scoring matrix. Cogwheel and Shield are ruled out because they in many regards are worse suited than the BMW 520 gear selector. Perhaps they would have had a bigger chance with a higher level of intuition integrated in the design and not being placed on the steering wheel, where the position cannot be constant.

6.4. CRITERIA SCORING

For the criteria scoring matrix, seen in table 6.3 on the following page, some of the criteria from Pugh's matrix are kept, and some have been replaced with others more relevant for the acceptance of the final solution. These are presented here:

- **Operable without looking** – does functions, shape and/or shift pattern help the user to quickly learn how to maneuver the gear selector without looking at it?
- **Low learning curve** – depends on familiarity and how easily the system is understood.
- **Freed space** – can the placement contribute to a larger space for the driver's body and legs, cup holders and other interior features?

The criteria are, as in Pugh's matrix, weighted depending on how well they contribute to the acceptance of the final solution [1]. How well a concept then is fulfilling a criterion is graded on a scale of 0-3.

Weight factors:
3 = the solution is fulfilling the criterion fully.
2 = the solution is fulfilling the criterion in large extent.
1 = the solution is fulfilling the criterion in some extent.
0 = the solution is not fulfilling the criterion at all.

The total points are calculated by first multiplying the weight of the criterion with the specific grade, and then adding up all points for each concept.

Table 6.3: Weighted Criteria Scoring matrix used for further evaluation and elimination

Concept / Criteria	*Weight factor*	*Flip-switch*	*Potato*	*Soft cube*	*Touch it*	*Scroll Pad*	*Turning Console*	*Bridge*
Accessibility	2	3	3	3	2	3	3	1
Ergonomic	1	2	3	2	1	1	3	2
Shift pattern understandability	3	3	2	2	2	3	2	2
Interactive display	1	3	2	2	1	1	1	3
Feedback	3	3	3	3	3	2	2	2
Operable without looking	2	2	3	3	0	2	2	3
Low learning curve	3	2	2	2	1	2	2	2
Freed space	1	0	0	0	3	3	3	1
Points Total	-	39	38	37	27	36	35	32

Shift pattern understandability, feedback and low learning curve are important criteria well discussed in the idea generating phase and are therefore weighted with three points. All concepts are deemed to have a high shift pattern understandability, where Flipswitch and Scroll Pad is given the highest grade. As for feedback, every kind is important, but touch is valued the highest, then hearing and last vision. Vision is of course essential for driving, and visual feedback is important. However, the design team considers it better if the driver can change gear without looking for feedback. If the driver is to change gear without looking for visual feedback, haptics plays a bigger part. All concepts fulfill the low learning curve criterion in large extent except Touch It, which is seen to have a higher learning curve.

As seen in the matrix, the five concepts with highest points are correlating with Pugh's results; Flipswitch, Potato, Soft Cube, Scroll Pad and Turning Console. Together with the ranking from the employees of KA in table 6.1, the design team will discuss the options and decide which three options will be further developed before making the final decision.

6.5. CONCEPTS FOR FURTHER DEVELOPMENT

The decision of which three concepts that will be taken into further development is based both on the opinions from KA and the two elimination matrices conducted by the design team. The elimination matrices were done as unbiased as possible, using facts instead of the design team's opinions. From the criteria scoring matrix, the top five concepts were ranked close to each other, ranging from 35 to 39 points. However, even though Turning Console is one of the five concepts, it did not receive more than one point from KA, so it will be ruled out.

The four concepts left now are Flipswitch, Potato, Soft Cube and Scroll Pad, and since the points are so close to each other, the design team decides to now allow their own personal opinions and feelings play part in the elimination process. The team is found of all four concepts and can see them as feasible gear selecting solutions. Flipswitch combines a sleek shape with a simple shift pattern and an invitation to a future within gearshift touch technology. Potato offers shift pattern robustness, comfort and upcoming cold-touch feature. Soft Cube also has an easily learned shift pattern, combined with clear directions of use and a slightly traditional design. Scroll Pad has a high news-value, is easily maneuvered and space efficient with a clear shift pattern.

Flipswitch, Potato and Soft Cube have the same location. Flipswitch and Soft Cube are both based on a joystick design and the shift pattern of Potato and Soft Cube are similar. Because of its similarities, both with the other concepts, and gear selectors on the market, the design team decides to rule out Soft Cube. This means that Flipswitch, Potato and Scroll Pad, seen again in figure 6.1, will be taken into further development.

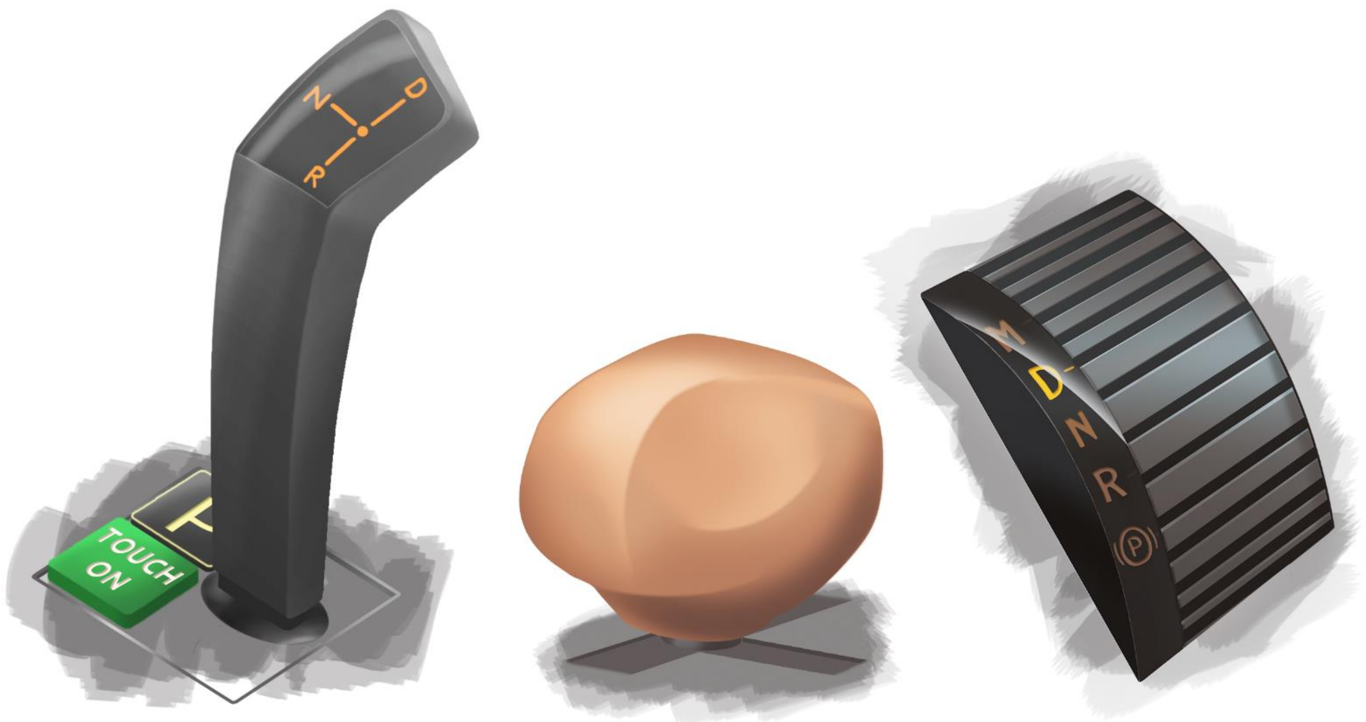


Figure 6.1: Idea concepts chosen for further deveolpment; Flipswitch, Potato and Scroll Pad

7. SECOND CONCEPT DEVELOPMENT AND ELIMINATION

THIS CHAPTER DISPLAYS CHANGES MADE TO THE THREE CONCEPTS REMAINING AFTER THE FIRST ELIMINATION PROCESS, AS WELL AS THE CHOICE OF A FINAL CONCEPT.

The remaining three concepts, Flipswitch, Potato and Scroll Pad, was brought back to the drawing table for another round of discussion and development. The design team considered if features with high potential from eliminated idea concepts could be integrated in the remaining. Flipswitch received a dual commando shift sequence on its touch screen, but otherwise, the concepts were decided to have their greatest potential as they were already designed. Scroll Pad received a comment from a KA co-worker on being old fashioned, but since the design team could not determine the cause of that feeling, it was overlooked.

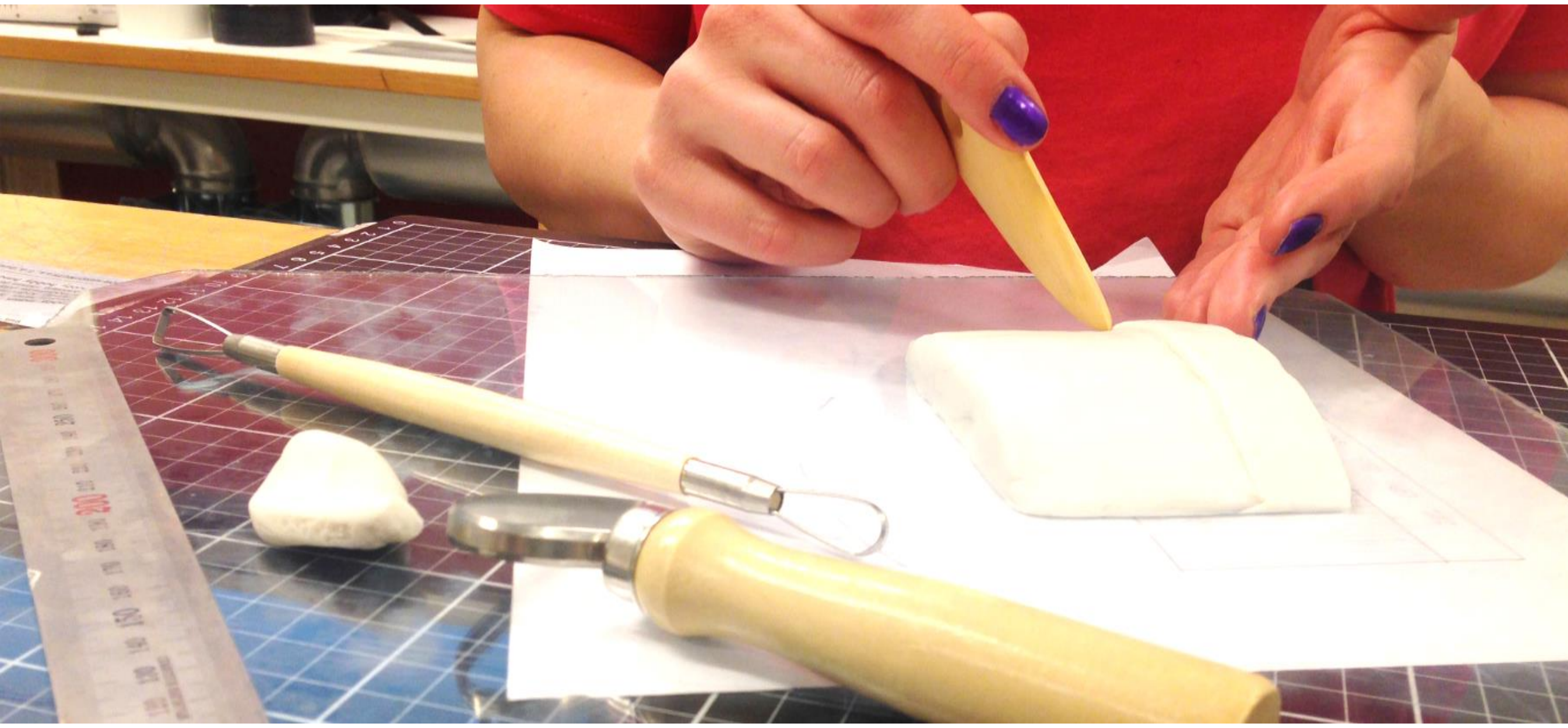


Figure 7.1: Building mock-up models in modeling clay

7.1. MOCK-UPS

In the next step, quick mock-up clay models are built in order to receive a tangible idea of the concepts' shapes and sizes, see figure 7.1 The finished clay models presented in 7.2 were first discussed within the design team and then with our KA advisor Jimmy Östman. The models were also shown to various students and teachers with different levels of driving knowledge, to see how they interacted with the models and thought the gear selectors ought to be maneuvered and gripped.

An issue quickly arose in the geometry of Potato. The concept is supposed to deliver a haptic comfort, but it was hard to achieve due to the diversity of hands. It was remodeled once, where the thumb ledge was less distinct, but without much progress in regards of comfort. The design team thinks Potato might not be comfortable for the masses, even though they like its robustness and shift pattern.

For the prototype of Scroll Pad, a fabric was used for the movable part, which did not deliver enough grip but was enough for the purpose of showing how to change gear. Since it shows an entirely new way of gear changing, some people were puzzled by it, while others liked it a lot. It is clear that there is a need for distinct steps for each gear, for the user to get feedback about when the gear is changed.

Flipswitch's model gave the design team a positive surprise, as the design turned out to be quite comfortable. It allows different grips depending on personal preferences and its tilted edges and rounded shape added to the sleek feeling.

Figure 7.2: Collection of mock-up models created during the second concept development

7.2. PMI

The clay models and the input they provided were used in a PMI analysis to list positive and negative aspects of each concept. Interesting aspects were highlighted and if they were considered as negative, a discussion regarding if they somehow could be changed and thereby become positive occurred. Some highlighted inputs are displayed in table 7.1.

Potato has good qualities of having an interesting shape and material, being space efficient and uses haptics by both connecting the shift pattern to the muscle memory and by its vibration. That is put up against its issues of being perceived as non-ergonomic and having a low detail level. Scroll Pad clearly shows which gear is chosen, is also space efficient and probably easy to use. However, it might be hard to use without looking and if a person uses gloves or has lower hand precision, the moving part might not allow enough grip. Flipswitch offers simplicity in its interactive shift pattern and design, can be gripped in different ways and integrates new technique. Although, the display might catch reflections and therefore be hard to see, and the design might be perceived as frail.

The PMI analysis resulted in a change of design both for Scroll Pad and Flipswitch. Scroll Pad's stable part is suggested to be slightly angled towards the driver to allow a better shift pattern impression. Also, stops ought to be installed at the top and bottom of the shift pattern, so that the movable part cannot be moved all the way around the pad. Flipswitch also receives an angled shift pattern. In its case, the whole top surface is tilted to allow the driver a better view of the shift pattern. Once the design team decided on the changes, the last elimination was conducted.

Table 7.1: The positive and negative features of the three leading concepts

+ Flipswitch	-
Shift pattern offers simplicity	Screen's shape difficult to manufacture
Graspable in several ways	Difficulties in seeing the screen
Easy to select gear without looking	Elegance vs. fargility might be a hard balance
+ Potato	**-**
Interesting material, cold touch	May be hard to design ergonomically for all users
Vibrational feedback	Lacks details, just a lump
Creates interesting connection to muscle memory	
+ Scroll Pad	**-**
Clear gear indicator	Hard to change gear without looking
Clear and easily glanced shift pattern	General acceptance might be tough
A whole new dimension of gear shifting	Surface may be hard to grip

7.3. COMPARISON MATRIX

The concepts are in the comparison matrix evaluated on one criterion at a time, as seen in table 7.2. To simplify the matrix, each concept is given a letter. Flipswitch is A, Potato B and Scroll Pad C. When comparing the concepts towards each other in each criterion, the concept with the highest level of acceptance or best fit with the criterion receives one point. If two concepts are equal in the task of performing a criterion, both get half a point each. The points are summed up first for each criterion and at the bottom in total.

Even though some criteria for the comparison matrix are similar to the ones used earlier in Pugh's decision matrix and the criteria evaluation matrix, they are here even more thought through. Understandability stands for both first impression and simplicity. Low learning curve refers to not only how well a user could understand the product, but also how the design itself encourages the user to use it correctly, even without prior knowledge.

As seen in the matrix, Flipswitch received more points than the other two combined. This depends both on its shape and simple shift pattern, which makes it possible to both quickly understand and use. The design team also believes it will deliver the best haptic feedback through its appearance, movements and feedback. Flipswitch is thus the concept chosen to represent the final result of this project. The remaining part of the project will focus on refining the concept and finalizing a representative prototype.

Table 7.2: Comparison Matrix studying the remaining three concepts on different criteria

Concept / Criteria	*Flipswitch* *A*	*Potato* *B*	*Scroll Pad* *C*
Understandability & simplicity			
A	-	A	A/C
B	-	-	C
C	-	-	-
Sum	1,5	0	1,5
Feedback			
A	-	A	A
B	-	-	B
C	-	-	-
Sum	2	1	0
Operable without looking			
A	-	A/B	A
B	-	-	B
C	-	-	-
Sum	1,5	1,5	0
Low learning curve			
A	-	A	A
B	-	-	C
C	-	-	-
Sum	2	0	1
Haptic experience			
A	-	A	A
B	-	-	B
C	-	-	-
Sum	2	1	0
Sum Total	**9**	**3,5**	**2,5**

8. RESULTS OF FINAL CONCEPT

THIS CHAPTER INTRODUCES THE FINAL CONCEPT IN ITS ENTIRETY. THE DESIGN, MATERIALS, SHIFT PATTERN AND FEEDBACK ARE PRESENTED IN GREAT DETAIL AND WITH ILLUSTRATIONS.

8.1. PRODUCT DESCRIPTION

As seen in chapter 7, Flipswitch is the concept chosen to be the final design of an intuitive electronic gear selector for cars with automatic transmission, with a general design of a joystick. It is a monostable gear selector offering the product segment new features, as well as design attributes and a location with recognition value. This together with an easily understood shift pattern and a clear feedback system are seen as features with a high potential of contributing to an intuitive interaction for a great variety of users. It has a sleek design and is positioned the left side of the center console, approximately leveled with the seat, see figure 8.1.

Figure 8.1: Flipswitch, the final concept, seen from between the front seats

8.2. DESIGN

A trend within the automobile industry observed by the design team during benchmarking, is to design gear shifters with a great deal of individuality, and so is Flipswitch. Apart from intuition, it has also been important for the team to provide the concept with functionality, aesthetic uniqueness and ergonomic features. An extra uniqueness is provided by its dual interaction possibility, where the user can choose whether to select gear by using the joystick function, or the touch function provided through a touch screen on the top surface.

Flipswitch is shaped to be thin and rather tall, which provides a sleek appearance. The front is flat with rather sharp edges. The back and the side surfaces are slightly bent and has great rounds in between, especially on the right side, to provide a comfortable grip. The top surface is angled forwards and rotated towards the driver to be easily glanced, and to provide a good grip especially for using the touch screen. Because of its dual functionality, it has to be comfortable in both interaction possibilities. This is provided by a concavity along the right side, which is sharper just beneath the touch screen, initiating a natural rest for the index finger, as seen in figure 8.2a. From that hand position, the touch screen is easily reached and used by the thumb. When using the joystick function, it is recommended to use the same grip for a good maneuverability, but it could also be held in other positions if so preferred.

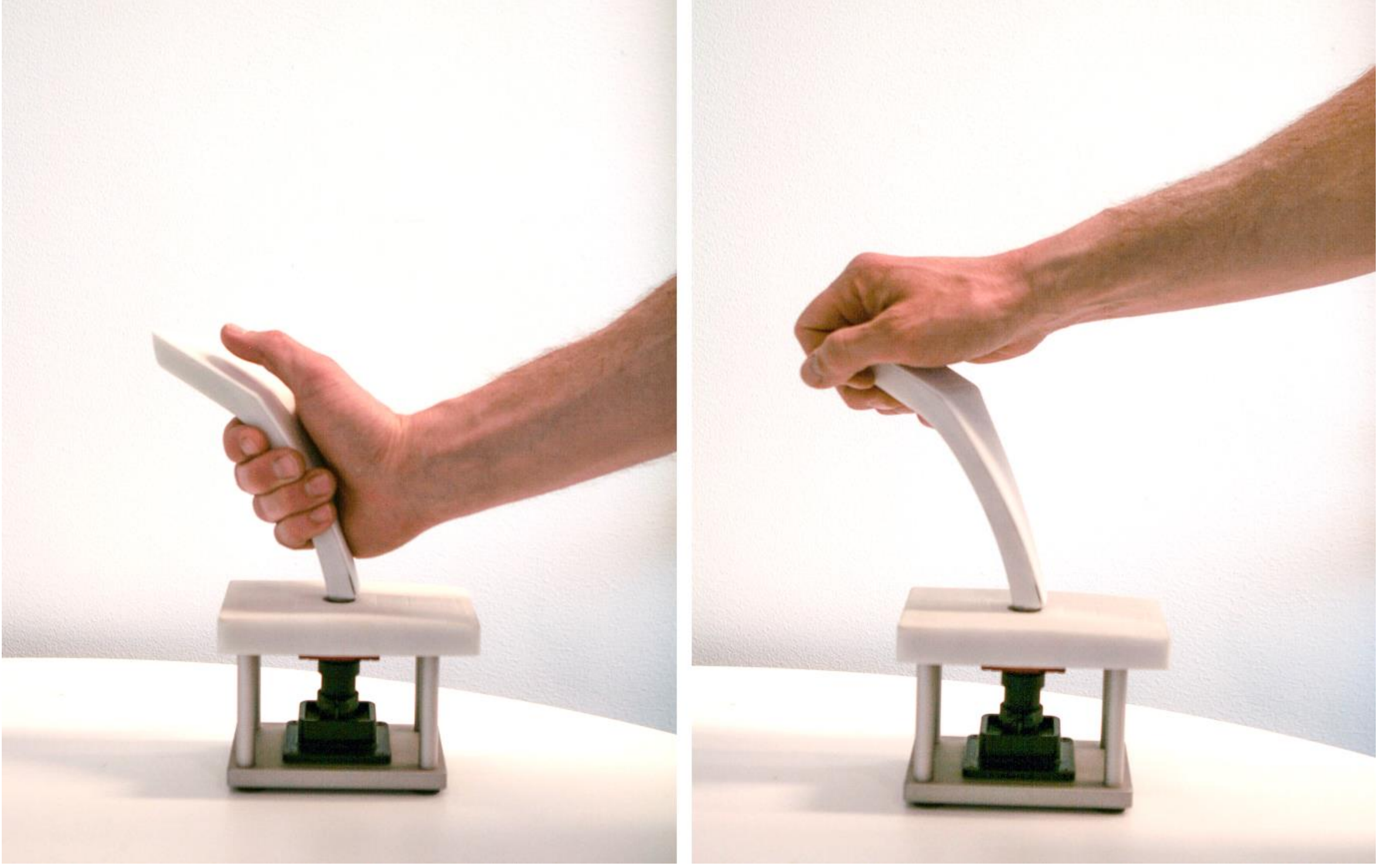


Figure 8.2: Two possible grips showed on 3D printed prototype; a) primary grip suitable for touch screen interaction and b) a secondary grip suited for joystick mode

Flipswitch's body is also designed with an angle towards the horizontal plane, seen in figure 8.3. For finding the optional angle, the clay prototype from the second concept development was brought into a physical car interior where it was held in different locations and angles. The most comfortable angle was found to be 60 degrees when the bottom part of the prototype was held in the same level as the top of the seat. When the prototype was brought into a car interior, it was also observed to have the possibility of an appropriate design for the modern driving environment, which is essential for the final solution.

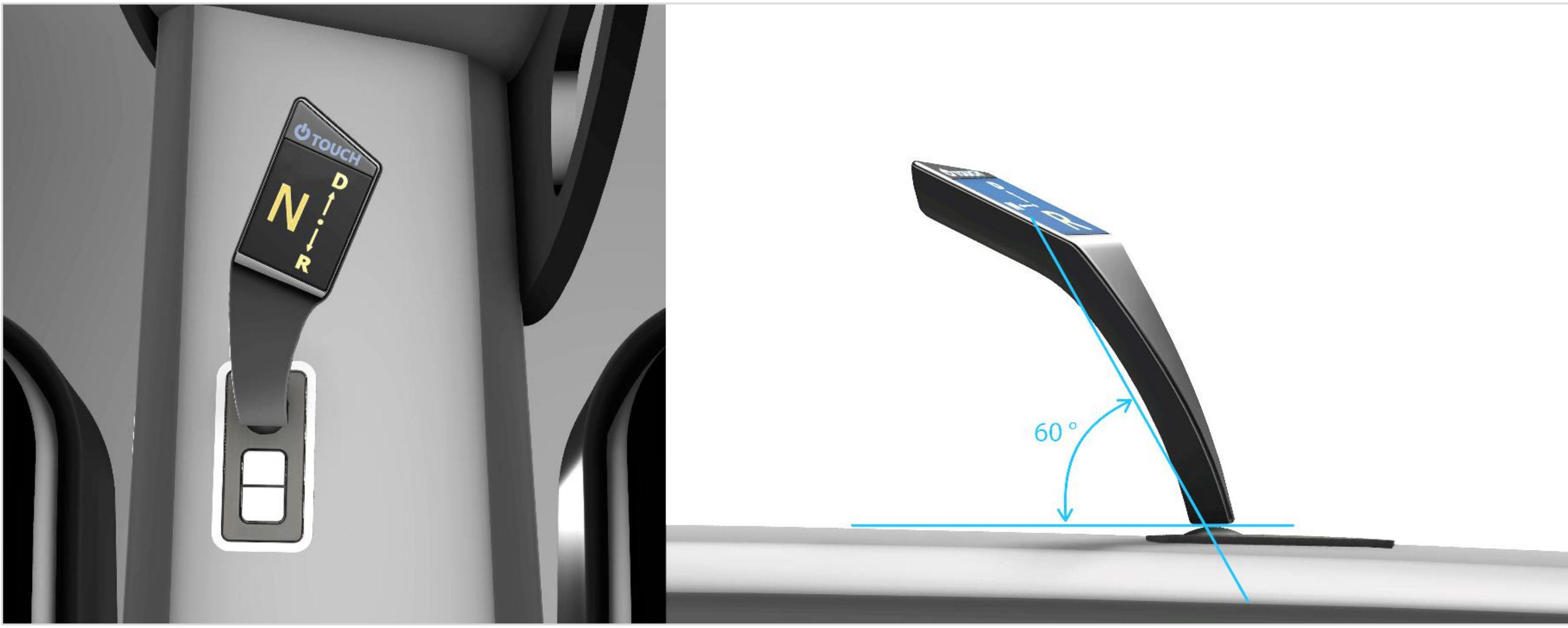


Figure 8.3: Flipswitch from above and left side with its 60 degree angle towards the horisontal plane

8.3. MATERIALS, COMPONENTS AND COLORATION

Flipswitch has the potential of being produced in a variety of materials and colors. For instance, it could be offered in one basic performance and one luxurious, available as an optional installment. The materials presented with the final concept are chosen to provide a vision of potential user experience and it is important to keep in mind that they are seen as suggestions that should be evaluated before production.

The joystick body consists of one front part and one back part, see figure 8.4. The front part has a touch screen and a button on its top surface. Both the front and back parts are given aluminum as material, to provide a robust feeling with a cold touch surface, which is not offered in the same extent by traditional plastic surfaces. They are both brushed and colored in a dark grey tone, to provide a metallic characteristic. The front side has a smooth and glossy finish to emphasize the general design's sleekness. The back part has a ruffled and matt finish to provide a nice surface to grip. The split line between front and back side is located at the body's sides, close to the front side.

The touch screen is a capacitive touch screen, providing a clearer picture and less reflection compared to a resistive touch screen, which is another common touch solution [31]. The touch on/off button provided above the touch screen is made of glass, to provide homogeneity with the touch screen's glass surface. It still works as a mechanical button with consistent background color and text.

Within the concept, there is also a base plate including two buttons, a frame and the base plate itself. The joystick itself is connected to the base plate by a rod, in line with the two buttons. The base plate itself is adaptable to the car's interior for creating a unity within the car, even though the system as a whole is made to stand out and show off as one unit. Both the buttons and the frame has the same material, color and structure as the front part of the body. Both the frame and the base plate has a little flexion in the surface. The buttons follow the base plate's surface, are split only by a small gap, and their corners follows the radius of the frames.

Figure 8.4: The essential parts of Flipswitch

8.4. HMI

Flipswitch is designed to offer a human machine interaction as intuitive as possible. Its fundamental characteristics and location can provide a potential user who has ever seen a traditional gear shifter a direct insight that this is the gear selector. Its appearance has similarities with products in the same product category, and it is located at the center console, which is a familiar location of existing gear selectors. The design team sees this as a first step towards a possible intuitive interaction.

Designing this system with dual input options, a joystick and a touch screen, is seen as bringing redundancy to the system. Different options can allow users to interact intuitively with the same system in different ways, according to the intuition research. The joystick function is the primary input option, since this is a way of interaction already known from the product category and therefore provides external consistency with similar products. The touch function brings new technology to the category and is considered to offer a high intuitive interaction to people already accustomed to touch screens.

When starting the car, the joystick mode is always the active mode, mainly to not create confusion when one car has several users, such as within a family or for people renting a car. The user who wants to use the touch function has to manually choose this option, and this is also the reason to why there is a touch on/off button, and not a joystick on/off button. Since Flipswitch is, to the design team's knowledge, the first concept to offer a gear selector with touch technology, the dual input options are also seen as providing a higher safety than a system providing only a touch option.

8.4.1. Shift Pattern and Gear Options

The accessible gear options are the fundamental ones for an AT, and the symbol to represent them are the ones seen as standard for automatic gear selectors. This for providing external consistency among products within the same product segment. The three gear options found in the shift pattern are D for forward propulsion, R for backward propulsion and N for neutral gear mode, see figure 8.5. When P is active, its letter is shown on the screen as well.

From the test driving, the design team found that forward propulsion was normally accessed by pushing backwards in the shift pattern, and backward propulsion forwards with N in between. This was perceived as confusing, so despite of current norms, Flipswitch is given another structure in its shift pattern. D is positioned forwards in the shift pattern, R backwards, and N to the left. Since Flipswitch is monostable, only one move is required for accessing each gear. When using the joystick, the driver accesses each gear by moving the joystick in the direction of desired gear. The same principle applies when using the touch screen, where any finger, but preferably the thumb, is used for swiping in the direction of the desired gear. The swipe has to end by holding for approximately one second in order to access the gear to avoid accidental gear shifting. As another safety feature, R can only be accessed when the vehicle has come to a stop and the service brake is depressed.

A button is provided on the top surface just above the touch screen, with which the user can turn on and off the touch function. When it is activated, the joystick stabilizes in its monostability point, so both functions cannot be used simultaneously. In this mode, the joystick can only be used with a great amount of force, such as often applied in a panic situation. The design team considers this as a safety attribute, but it has to be evaluated further.

The system provides another two gear options; P for park position and a downhill mode. These are seen as secondary features that are not used as frequently but are still valuable for the driving experience. Therefore, they are not offered through the shift pattern, but through the two buttons on the base plate. The P button is placed closest to the joystick, since this function is expected to be used more frequently than the downhill mode. The user can turn off the engine in any gear, but P is automatically engaged to prevent the vehicle from moving, and is thereby the active gear once the engine is started again. To shift out of P, the service brake must be depressed, and from there shift to desired gear. To activate P manually, the button is pressed when the vehicle has stopped completely. Even though the transmission prevents the vehicle to roll when P is active, it is recommended to also use the parking brake when parking the car, especially in inclines. This in order to prevent roll away and to increase the life of the transmission.

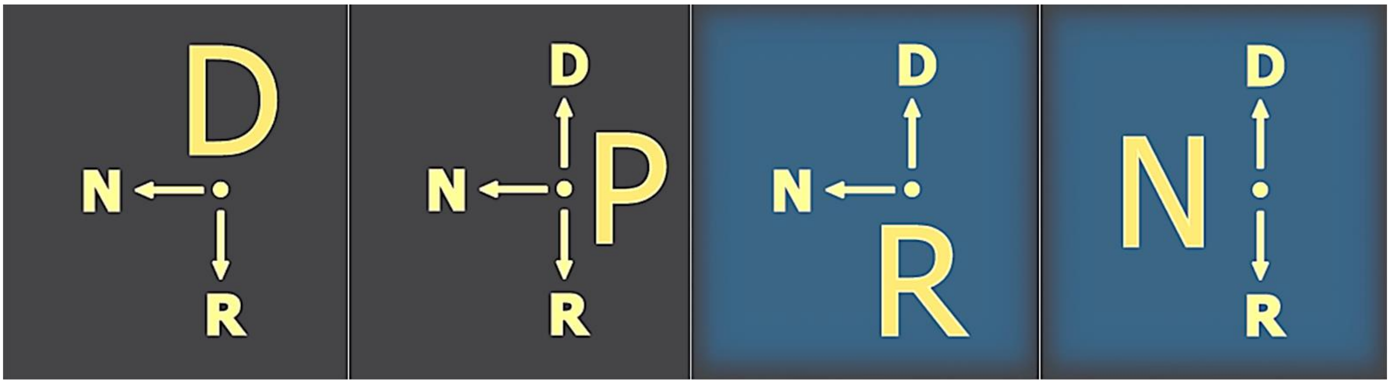


Figure 8.5: Gear options available in the touch display. Dark grey background for joystick mode in a) & b), and blue background for touch mode in c) & d)

A gear option for manual gear shifting, M, as found in many AT:s, is not offered by Flipswitch. This decision is based on the design team's conclusion that fewer gear options may offer a higher grade of intuitive interaction and the unnecessity of manual shifting in normal automatic driving. M is also used for not tearing the brakes as much when driving downhill, for which Flipswitch instead offers a downhill mode. The downhill mode, accessed by pressing its button on the base plate, can be active all the time, as a supplement to D. It is planned to realize when the car is driving downhill, engage a lower gear and thereby makes the engine brake work instead of the service brake. When active, the downhill button is illuminated and to deactivate, the button is pressed again.

8.4.2. Feedback

The system is designed to provide the user with clear feedback for a successful action. Feedback is mainly given visually through the touch display and instrument cluster, and haptic through the gear change movements. When engaging reverse, an additional sound confirms the chosen gear. The sound is merely one soft beep, to not be perceived as annoying or stressful.

When the door opens, the touch screen lights up just as the interior lights do. This makes it possible for the user to see the shift pattern already before the car is turned on. As seen in figure 8.5, a permanent dot in the center of the shift pattern represents the joystick's monostable position. When park position is active, P is shown to the right of the dot, and the gear options D, N and R are shown at their respective positions with an arrow pointing towards each one of them. This to show the user in which direction to swipe or move the joystick to access desired gear. When moving from P to one of the other three options, P disappears from the shift pattern, and the new chosen gear is instead enlarged and its arrow vanishes. See figure 8.5b, where P is chosen, and 8.5c, where R has been chosen.

The interactive shift pattern on the touch display is identical whether the joystick or touch is used as input function. The same interactive shift pattern is also provided in the instrument cluster. On the touch screen, the gear options are shown in a bright yellow color with a high contrast to the background. When the joystick is in use, the background has a dark grey tone, similar to the joystick itself, to visually create a unity between its body and display. The purpose of this is to tell the user that the whole joystick is used in that mode, and the screen only provides output to the user. When the touch screen is active, the background color is dark blue to differ from the joystick itself. This to indicate that the touch screen is now used as a separate unit for both input and output.

When any of the three available buttons are active, their text glows and they stay leveled with their surrounding area. One reason for this is design aesthetics, since the downhill mode for example can be active for a long time. A pressed button would result in a diffusion of a surface that is designed to be smooth. Also, since P can be activated and deactivated without the button, it makes more sense if it is kept in one consequent level. The final reason is that the glowing text or letter is seen as enough feedback to tell the user that the function is activated. Since the downhill mode stays active until the user deactivates it, a symbol for active downhill mode is also shown in the instrument cluster.

Two clarifying notifications are designed to provide feedback in the instrument cluster. The first one says "swipe and hold to change gear" and is always shown when the touch function is activated. This to clarify for first time users that just swiping is not enough for successful gear change when using the touch screen. It also serves as a confirmation that the touch has been activated. The second notification says "depress service brake to exit P", and is only provided when the driver tries to switch out of P without using the service brake.

9. DISCUSSION

THIS CHAPTER REASONS FOR THE PROJECT'S PROCESS, DESIGN CHOICES AND FINAL CONCEPT. IT ALSO DISCUSSES FURTHER DEVELOPMENT ASPECTS.

9.1. PROCESS OF PROJECT

To line out the project's time frame, a GANTT-chart was created in the first week. The chart has served as guidance for how much time ought to be dedicated to each task. Two versions of GANTT-charts has been made. The first one had a schedule so pressed that it soon became unachievable, due to courses the design team took simultaneously and because the initial research needed more time than planned. Since the research is the backbone of this development project, the design team agreed to rearrange the GANTT-chart in a newer version, that can be found in appendix 1. A few changes has been made in the chart since, which has pointed out the importance of every step in the design process. In hindsight, construction and selection of materials would preferably have been given more time.

The methods used throughout the project has all been of great value for both the progress and result. The design team prompts that the customization that occurred in several methods has been helpful to better put them within the project's scope. Perhaps a different approach would have led to a different result, but the design team believes that several of the idea concepts and final concept presented in the project can be used by KA if they look for intuitive and non-conventional solutions.

9.1.1. Theory and Market Research

The research was conducted both by a field study test driving and literature research. The test driving experience gave the design team a great introduction to SBW gear selectors, since their previous gear shifting knowledge was limited to manual gear selectors and mechanical AT's. The hands-on knowledge of SBW was a great complement to the literature research conducted on the subject.

Intuition and intuitive HMI have also been thoroughly researched, since it is the leading keyword for the project. The general knowledge of the meaning of intuition has been confirmed and improved. The research was mainly conducted through reliable online sources, both articles and acknowledged studies. Perhaps a wider general knowledge of intuition and its HMI could have been discovered if a survey connecting intuition with SBW had been conducted. Due to the limited time frame and the knowledge already gathered with the literature research, this was however not done. The research took more time than planned, but in hindsight that is thought to be a good thing since it has proved to be good knowledge for the development that followed.

Whether it would have been more educative to research SBW, intuition and interaction before doing the test driving can be discussed. Perhaps the findings would have been of a different kind then, with more facts and understanding of why the systems reacted as they did. Still, an aim for the project is that anybody with a driver's license should be able directly understand how an unknown gear selector, which ultimately is this project's end concept, works. Therefore, it was decided that live experience of existing gear selectors is better seen without the knowledge of intuition, interaction and SBW.

9.1.2. Concept Development

The project's design development followed a traditional path of modern product development and used well-known methods of idea generation. One could argue that more time should have been utilized for this step, and that more or other methods of ideation should have been used, for example the Ishikawa Diagram or a Morphological Matrix. However, the design team claims that the methods chosen has been well suited for the project's problem description and solution path. The number of methods and time spent using them relates to the team's size of merely two members. This has affected the possibility of making an even more substantial process. It is also important to keep in mind that this is a bachelor thesis and thus not as thorough as a master thesis.

An essential part of the ideation was to specify placements for solutions. The placement map found on page 31 structured the design team to focus on one area at the time and thereby made it easier to come up with innovative and concrete ideas fit for a specific position. The map also contributed to "outside the box" thinking, and even though placements were set they were seen as guides rather than limitations. The design team is satisfied with the chosen placements and the variety of ideas created around them.

The visualization of the nine idea concepts, whose posters can be seen in appendix 3, was the last step carried out in the first round of ideation. The posters were used for the design team's own advantage, because it helped them understand each others' ideas and to have something more feasible to discuss. The posters also served the purpose of a mid-project presentation at KA for co-workers in the SBW-field, which was a great chance for the team to validate their concepts and see which of them were thought to have the highest potential of reaching the market.

The second round of concept development occurred after the first stages of evaluation and elimination, and was kept quite brief. The aspiring three concepts were discussed and created in modeling clay. Whether the mock-ups ought to have been created at this stage or earlier can be argued for. Perhaps the understanding of the nine idea concepts would have been greater if they also had physical models. Even so, the design team claims that the posters used for the first elimination was enough material.

9.1.3. Evaluation

The two evaluation and elimination stages narrowed down the ideas first to three, then to one concept. Also here, as in the ideation phase, the selected evaluation matrices and their criteria can be discussed. Finding good criteria for the elimination methods was challenging, but the design team is sure that the chosen criteria are relevant and regards the task from every angle. They are anchored in the findings of the initial research of foremost intuition, but also HMI, interaction and SBW.

In the first elimination, the comments from KA co-workers regarding the nine concepts were taken into account and weighed as heavily as the design team's decision matrices. Fortunately, the opinions of KA correlated well with the decision matrices and could therefore be used to easily narrow down the concepts further.

Soft Cube was in the top three concepts both by KA and the decision matrices, but was still not taken into further development. The design team argues that there are too many similarities between Soft Cube and gear selectors already existing on the market, for example Audi Q7 and A6. The design team decided that the fourth best concept, Scroll Pad, should be taken into further consideration instead. The argument for this is that Scroll Pad were only one point below Soft Cube in both elimination matrices, and would add a completely new dimension to the gear selecting segment. The group thinks that this degree of choosing liberty has lifted the results, even though Scroll Pad is not our final concept.

9.2. FINAL RESULT

The final result is Flipswitch, a gear selector with joystick characteristics, a simple shift pattern, sleek design and touch screen for dual interaction. Because of its simplicity and dual interaction possibility, the design team thinks it will attract a large amount of users to interact with it intuitively. The design team is confident in their solution, but also acknowledges that other concepts presented in this project, and solutions not contemplated, might deliver intuitive interaction as well.

9.2.1. Design

The sleekness in Flipswitch's appearance was present from the very first sketch, even before it had an accentuated bend or touch display. Features that have been added and changed throughout the process, such as the rotated shape and shift pattern, has strengthened the design and ease of use, as well as guided the transaction from sketch to finished prototype. The final design suggests one primary grip, but allows the gear selector to be gripped in different ways. This since the design team believes that the individual freedom of interaction is an important aspect.

The very first sketch that Flipswitch is based upon, is both suited for the center console and behind the steering wheel, ergo the concept Bridge that was eliminated in the first elimination. Since one of the reasons Bridge was eliminated was due to its location, it can be argued that the center console is indeed a better placement for an intuitive gear selector. The fact that all concepts remaining in the second development stage were located somewhere on the center console also strengthens this argument.

The material chosen for Flipswitch is primarily aluminum, suggesting it is a premium add-on since it will be more expensive to produce than a plastic gear selector. In addition, using metal will provide the gear selector with cold touch, something that according to KA is on the rise within car interior design. Although, to make it available to a broader market, the design team agrees that it can also be produced in plastic, with the preference of keeping the assigned colors and surface finishes of a dark gray glossy front and matt back. In the ideation phase, bamboo was also discussed as material. This was however overruled, both due to the problems of integrating it with the car interior and complications of manufacturing. To have details in another material or color have also been discussed, but the design team reasoned that it might jeopardize its simplicity.

9.2.2. Touch Screen

Flipswitch's touch function adds an exciting new dimension to the gear selector, since it is to the design team's knowledge a fairly unexplored territory. When discussing the intuitive interaction with the touch display, arguments regarding haptic feedback and dual input possibilities can be raised. The design team admits that some parts of the user segment might have issues understanding the touch screen. This is the main reason why it has to be consciously selected every time the car has been restarted. The simple shift pattern is designed to be easily learned with only one motion direction per gear. In addition, a signal occurs both in touch- and joystick mode, indicating that R is selected. With these arguments considered, the design team argues that the touch function will have a better chance for acceptance.

To change gear in touch mode, the user swipes and holds on the display, preferably using the thumb. For first time users, this might not be an unconsciously understood action. A message instructing the user how to change gear is therefore shown in the instrument cluster whenever the touch screen is activated, advising you how to change gear. Whether this is the best solution or not can be argued for, because preferably no instructions would be necessary.

When the touch screen input is active, the joystick is locked and can only be moved with great force. Naturally, it can be questioned if this is intuitive and in line with the in-system consistency, but the design team sees this as a safety measure. If it would be just as easy to change gear with the joystick when the touch screen is active, the joystick might get moved unintentionally by careless users. If the driver is in a panic situation, it is presumed that he/she will use a greater force to try to move the gear selector, in which case it will be moved accordingly. The design team acknowledges that this is a feature in need of further testing and evaluation.

As for most touch screens, a user wearing gloves without touch capability will not manage to change gear. One option could be to provide heating within the gear selector when it is cold outside. Otherwise, this is an ideal situation for using the joystick mode.

9.2.3. Base plate

The base plate offers the two secondary features park position (P) and downhill mode. In the idea concept presentations, some concepts had the parking brake integrated in the shift patterns P-mode. Even though it is not integrated in Flipswitch's button, it can still be argued for if it should be. The gear selector's P-mode and the parking brake have similar symbols and even though they mechanically perform different actions, they carry out the same result for the user in modern cars. An integrated parking brake would decrease the number of features important for the driver and hence perhaps increase the intuitive interaction. In addition, some drivers used to AT tend to not use the parking brake, since they consider the gear selector's P enough even though it is stressful for the gearbox. According to KA, a feasible solution where P-mode and parking brake are integrated is being researched [13]. If a feasible solution is developed, the design team recommends further development of this thought. Especially the design of a symbol explaining this new combination of park position and hand brake.

The second button offers a downhill mode. When active, it is intended to provide beneficial engine brake which is helpful and economical when driving for example down a steep hill or in city traffic. When driving downhill with an AT, the user might perceive that the car is speeding, even though the user is not pressing the gas pedal. With the downhill feature, the engine will stay on a lower gear, and thus provide engine brake that will keep the speed leveled. Consequently, the driver does not have to press the brake pedal, and will therefore not tear on the brakes unnecessarily. The design team sees this as a relevant feature, but if a potential car manufacturer would prefer another feature, the design team embraces such ideas. Although, it ought to contribute to decreased emissions and should not interrupt the intuitive interaction possibility.

9.2.4. HMI

The shift pattern of Flipswitch is very simple, especially in relation to its monostability. The design team is aware of that this shift pattern is disagreeing with current common “P-R-N-D” shift patterns, where D is accessed by pushing the gear selector backwards. However, in reason with intuition, the design team claims that D ought to be accessed by shifting forwards, and it is time that a change happens within the shift pattern norms. The design team also claims that the solution is different enough from current common shift patterns to be accepted. In addition, by pushing N to the left side and placing P as a button, the shift pattern becomes easier to learn and use without looking at.

Whether Flipswitch’s channels of feedback is sufficient can be discussed. In eliminated concepts, vibration was for example suggested as haptic feedback. Perhaps this would have worked in this system as well, but chances are that the user would have been overwhelmed if such feedback was offered as well. The design team believes that the suggested visual, haptic and audible feedback channels are enough, especially in regards of the easy shift pattern. If for example an M or S mode would have been present, an additional feedback channel might have been desired.

9.3. FURTHER RESEARCH AND POSSIBILITIES OF IMPROVEMENTS

Engineering every aspect of a gear selector takes a crew larger than this design team over a year to fulfill [13]. Therefore, the prototype with its CAD file and additional information delivered to KA is not sufficient for manufacturing, but will be a good carrier of the concept's foundation and design aesthetics for further analysis and development.

Flipswitch will need further development in order to be producible, implementable as well as both economically and environmentally sustainable [1]. Mechanical properties have to be further developed, pinpointed and then analyzed through for example FMEA, FEA and DFM analysis, which evaluates the product’s failure and effects, abrasion resistance and manufacturing adaptability, respectively. Quality and tolerances also need to be decided, but they depend on which brand and model of car the gear selector is implemented in.

Electrical and embedded features need to be developed, especially for the touch function. The design team offers pictures of how the display and shift pattern is intended to look and function, but it still needs to be programmed. The movements of the gear selector also needs to be mechanically and electronically developed, so it will move and respond correctly. Reliance and safety tests are thereafter to be conducted as well.

In correspondence with that the producibility is evaluated and developed, implementation studies need to be conducted. The design team has used its knowledge regarding ergonomics, intuition and interior design when developing Flipswitch. Nonetheless, its appearance and intuitive capacity still need to be experienced and verified by various potential users in a usability study.

Lastly, its economic and environmental sustainability need to be estimated. For example, a cost analysis would calculate costs for development, production, market introduction and after sales [1], and it is important that the numbers add up for Flipswitch to be feasible. Flipswitch is suggested to use aluminum for its surfaces as well as a touch display. In relation to other gear selectors on the market, the design team believes the production costs will be higher. One suggestion is to offer the gear selector to a premium market, but costs can also be reduced by replacing aluminum with plastic. If offered in several materials, it is even more important to do a thorough abrasion analysis, since the different material properties might affect the product differently, due to its slim design. However, this change would probably cause a loss of user experience. A survey where materials are displayed and evaluated could help deciding whether a standard and premium gear selector is of interest.

Sustainable development and a long life cycle is of great value to KA, according to their three policies of environmental evaluation described in chapter 4. Therefore, a life cycle assessment (LCA) can be conducted to further evaluate the environmental impacts of the product throughout its life [1]. It accounts for every step, from development to waste and recycle management, including spare part evaluation.

Figure 9.1: The final concept rendered into a modern driving environment

10. CONCLUSION

While designing a gear selector with high intuitive interaction capacity based on shift-by-wire technology, important aspects to keep in mind has been understandability, consistency and feedback. The conducted initial research has proven valuable in every step of the design process, as it broadened the design team's understanding of intuition, SBW and HMI, as well as refreshed their knowledge about ergonomics. Following the traditional product development process has proved valuable in understanding the depth and importance of a well executed project.

The final concept fulfills the aim and deliverables mentioned in the introduction of this report by being appropriately designed for a modern driving environment. It is also, by the design team's judgement, easily understood by any user familiar with the conventional AT gear option symbols, D, N and R. It has the ability to communicate effectively with the driver by both being easy to use and giving relevant feedback through visual, haptic and audible channels. Additionally, it correlates with current legislative demands.

For this concept to be brought to market, further research and development is needed concerning embedded and mechanical features. Its intuitive integration in the driving environment seems with the conducted research promising, but also needs to be evaluated through usability testing.

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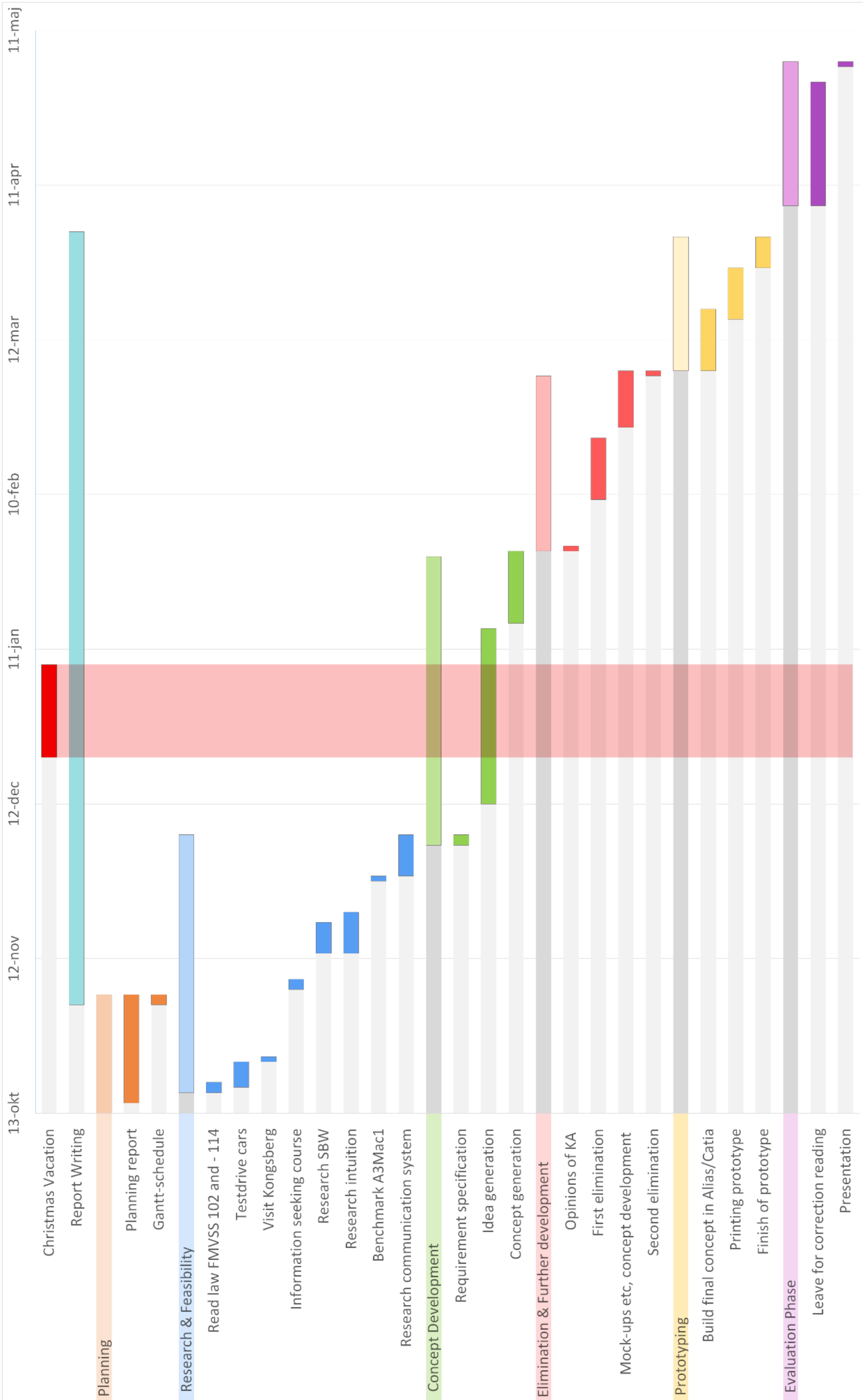
APPENDIX 1 — GANTT SCHEDULE VER 2.1



APPENDIX 2 — RELEVANT PARAGRAPHS FROM LAW FMVSS 102

S3. Requirements.

S3.1 Automatic transmissions.

S3.1.1 Location of transmission shift positions on passenger cars. A neutral position shall be located between forward drive and reverse drive positions.

S3.1.1.1 Transmission shift levers. If a steering-column-mounted transmission shift lever is used, movement from neutral position to forward drive position shall be clockwise. If the transmission shift lever sequence includes a park position, it shall be located at the end, adjacent to the reverse drive position.

S3.1.4 Identification of shift positions and of shift position sequence.

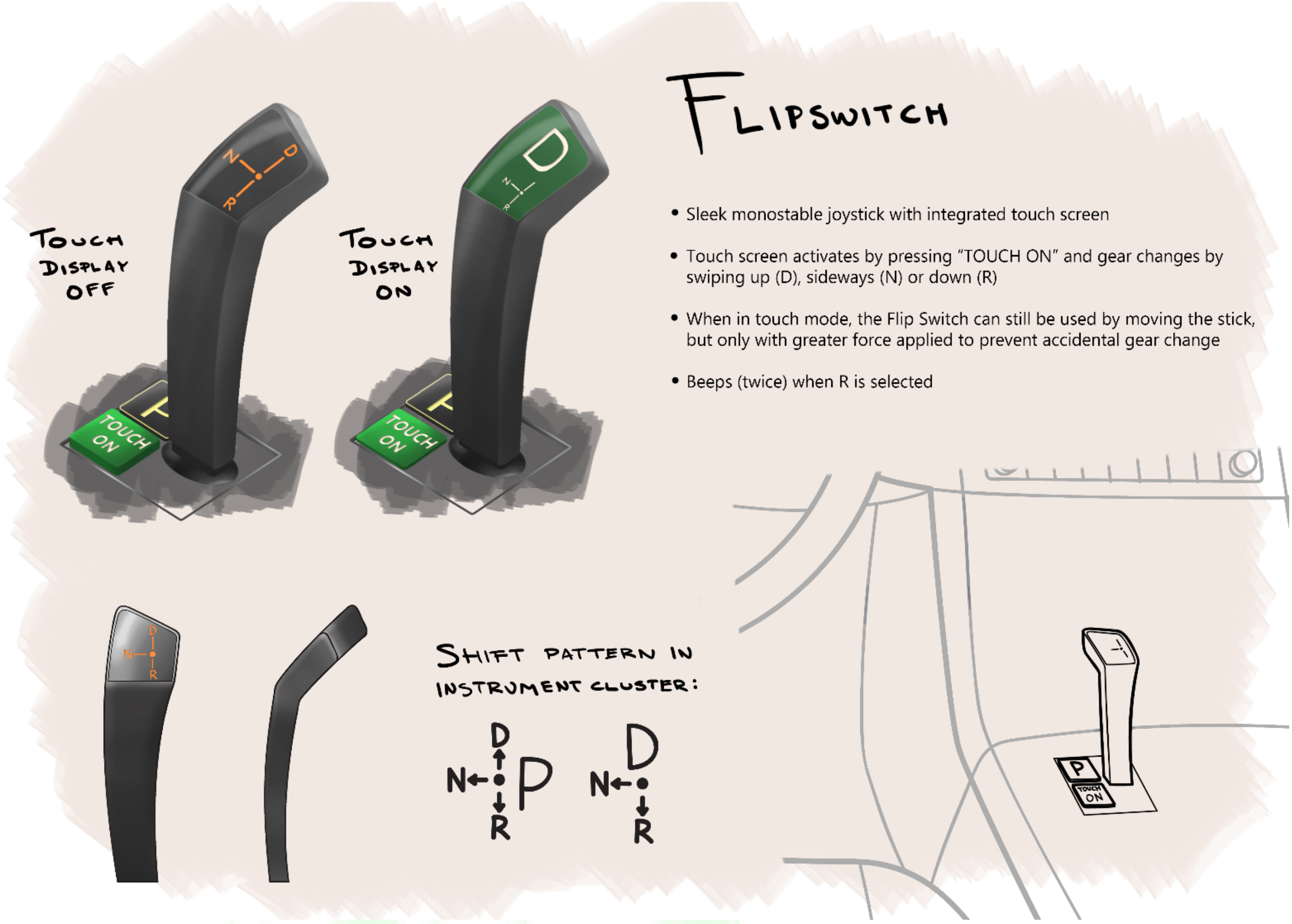
S3.1.4.1 Except as specified in S3.1.4.3, if the transmission shift position sequence includes a park position, identification of shift positions, including the positions in relation to each other and the position selected, shall be displayed in view of the driver whenever any of the following conditions exist:
(a) The ignition is in a position where the transmission can be shifted; or
(b) The transmission is not in park.

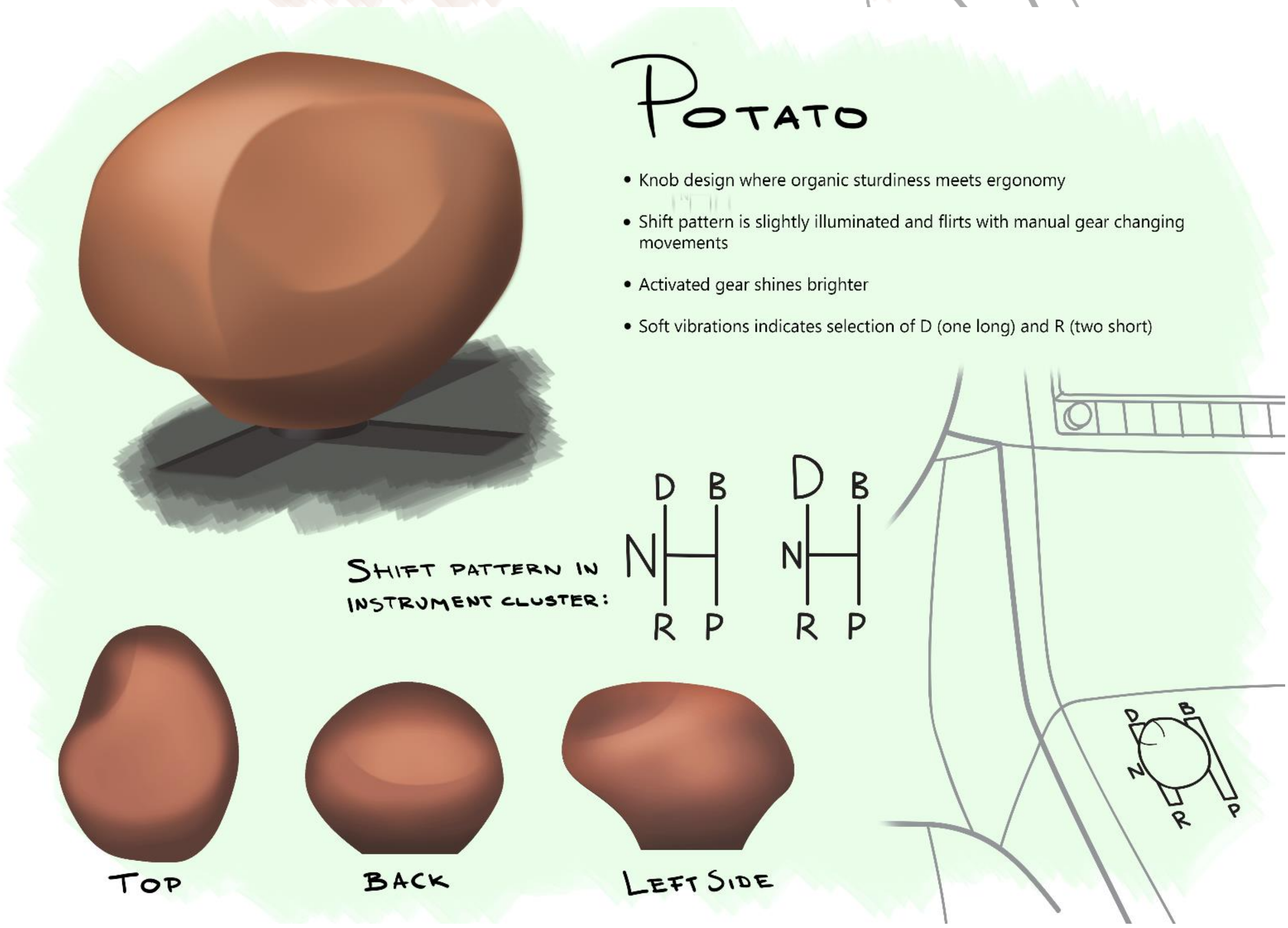
S3.1.4.2 Except as specified in S3.1.4.3, if the transmission shift position sequence does not include a park position, identification of shift positions, including the positions in relation to each other and the position selected, shall be displayed in view of the driver whenever the ignition is in a position in which the engine is capable of operation.

S3.1.4.3 Such information need not be displayed when the ignition is in a position that is used only to start the vehicle.

S3.1.4.4 All of the information required to be displayed by S3.1.4.1 or S3.1.4.2 shall be displayed in view of the driver in a single location. At the option of the manufacturer, redundant displays providing some or all of the information may be provided.

APPENDIX 3 — FULL POSTERS OF THE NINE IDEA CONCEPTS





Touch It

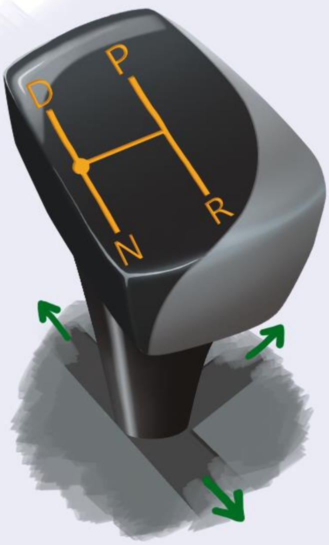
- Diamond shaped touch display framed in brushed silver
- To access D, swipe down and tap on the display, to hear a faint "click"
- Selected gear is centered, brighter and larger than the others, but the whole shift pattern is always visible
- Question mark blinks when information might be needed, and when tapped, an information box pops up on the display

Shift pattern in instrument cluster:

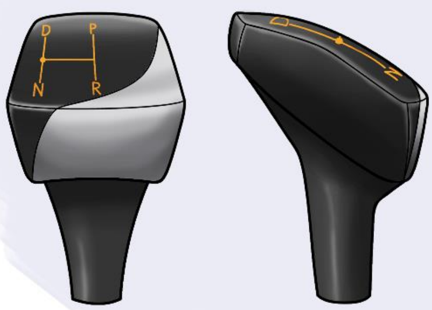
GEAR: D

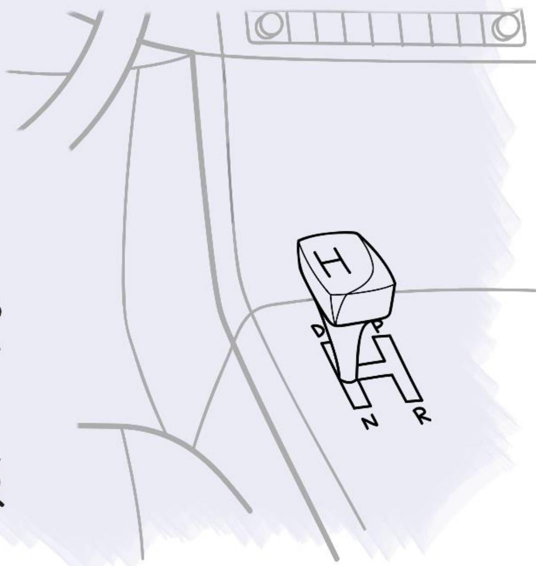
PARKING

Soft Cube

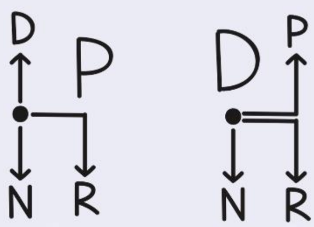


- Slightly traditional design comfortable to the hand, but with modern top display and brushed silver detail
- Smooth top with backlit shift pattern, where selecter gear is illuminated
- Shift pattern inspired by manual gear changing movements, allowing stick shift drivers to ease into SBW driving
- Soft vibrations indicates selection of D (one long) and R (two short)





Shift pattern in instrument cluster:

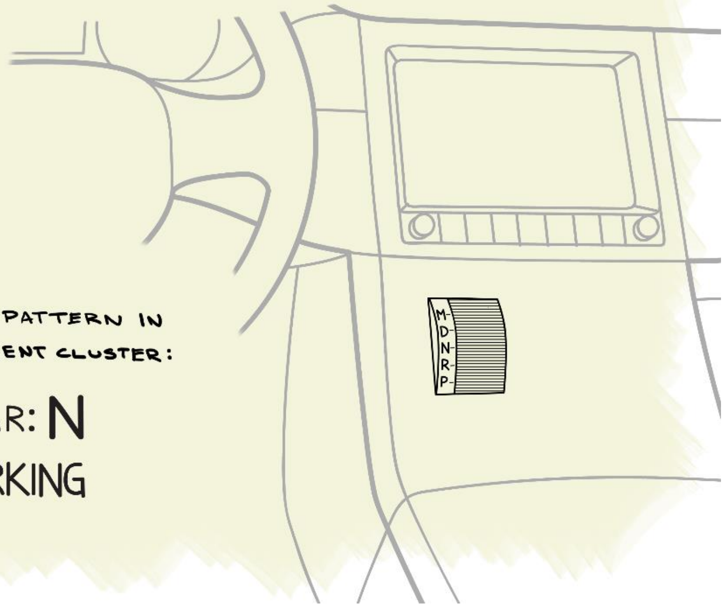


Scroll Pad

- Curved pad containing of one fixed part with a backlit shift pattern and one grip friendly multistable gear selecting part inspired by a travelator
- A haptic resistance indicates when a new gear is selected
- Active gear and a small bar next to it are lit up
- Can with advantage be placed slightly angled towards the driver

Shift pattern in instrument cluster:

GEAR: N
PARKING

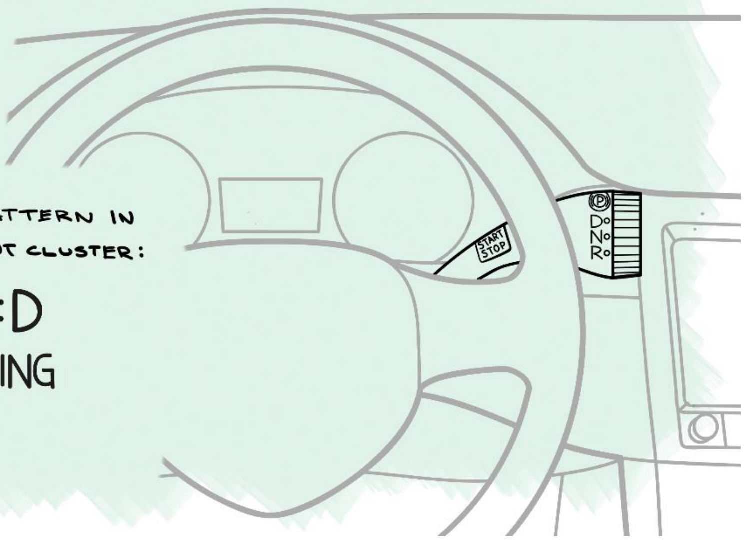


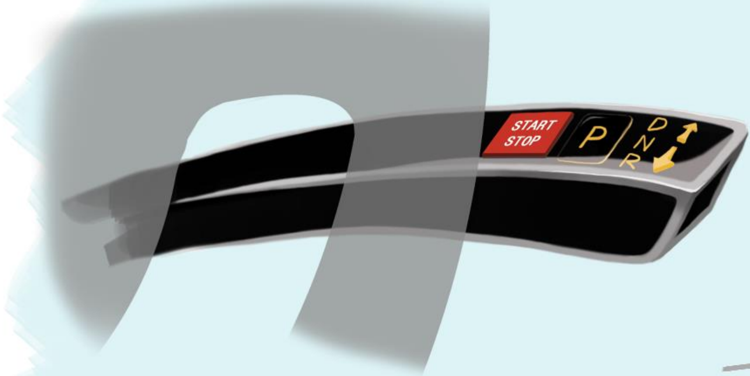
Turning Console

- Sturdy console with backlit letters and a grip friendly rotating gear changer at the end
- Gear changer and shift pattern is placed outside the steering wheel to always be visible
- A gear chance is indicated by a resistance when rotating and by a light next to the gear's letter
- Integrated engine start/stop button visible through the steering wheel

Shift pattern in instrument cluster:

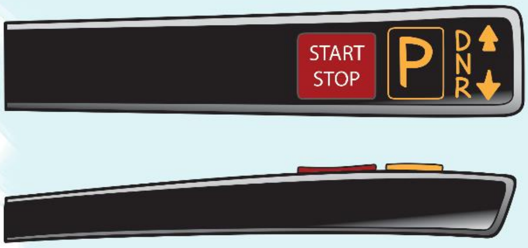
GEAR: D
PARKING

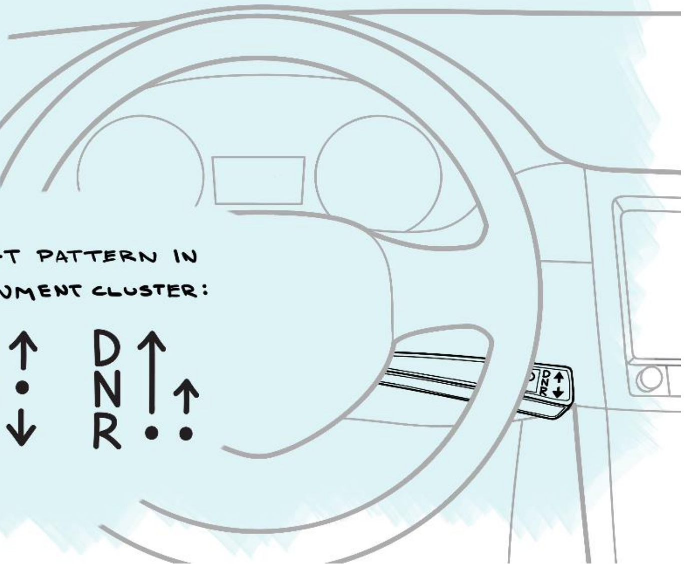




Bridge

- Monostable streamlined design with accentuated edges and backlit shift pattern
- Change gear by pushing it forward or backward (instead of up and down like the windshield wiper)
- Selected gear shines brighter, and a soft beep occurs when accessing R
- Start button visible when looking slightly from right



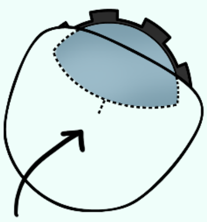


Shift pattern in instrument cluster:

D ↑   D ↑
N •   N ↑
R ↓   R • •

Cogwheel

- Illuminated buttons and monostable turning wheel with grip friendly cogs
- Gear change voice command available through the push of a button
- A haptic resistance in the turning wheel indicates when a new gear is selected
- Beeps (twice) when R is selected

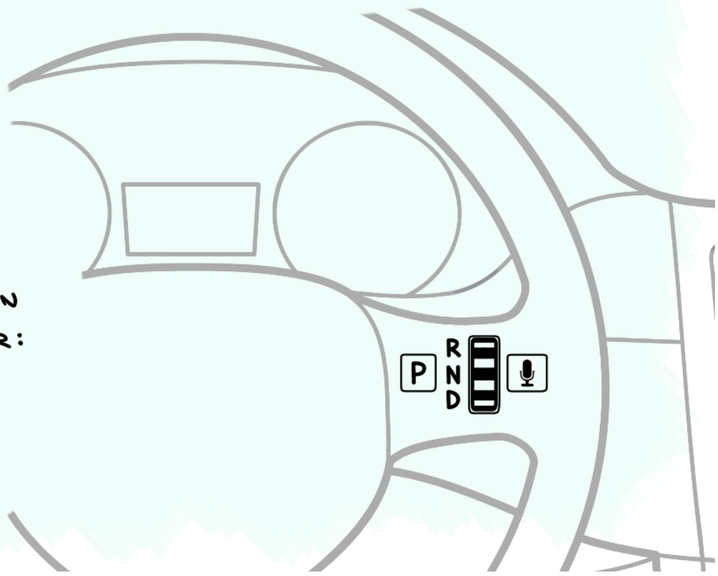


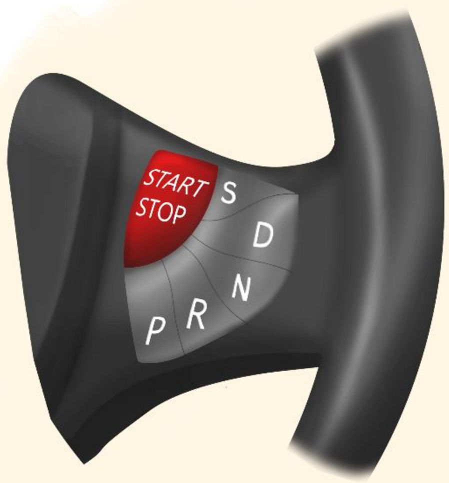
Sensor

Shift pattern in instrument cluster:

GEAR: D

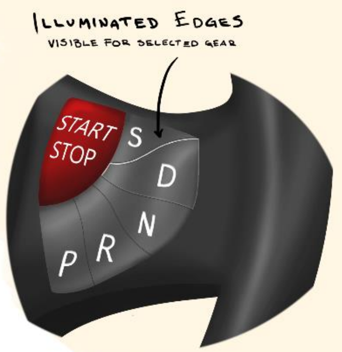
VOICE COMMAND





Shield

- Platform with buttons in brushed silver with backlit letters
- Provides an easy overview, and different shapes of buttons makes gear change possible without looking
- Selected gear's button glows and stays pressed down
- Engine start and stop button distinguished with different color and surface



Shift pattern in instrument cluster:

GEAR: D

PARKING